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THERMAL ANALYSIS TESTING TO DETERMINE THE COMPATIBILITY OF PROPELLANTS WITH PLASTICS

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THERMAL ANALYSIS TESTING TO DETERMINE THE COMPATIBILITY OF PROPELLANTS WITH PLASTICS

Final Report

(May 23, 1972 To May 23, 1973)

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By

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13. ABSTRACT

The objective of this program was to evaluate the stability of several propellants when aged in contact with plastic adhesives and foams. These data are required for application to Navy gun propulsion technology. The test program described in this report was performed using thermal analysis techniques to evaluate the compatibility of propellants M-26, PYRO and NACO with a variety of plastic adhesives and foams. The data generated give a statistical measure of propellant stability during aging in contact with the plastics. No data were generated regarding the effect of the propellant on the plastic materials.

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1. INTRODUCTION

Recent developments in the field of polymer chemistry are being used increasingly in current munition design. Increased use of plastic materials is due to their fabrication flexibility, high strength-to-weight ratios, and low cost. However, in munitions, plastics are often used in direct contact with propellants or explosive materials. To ensure safety in handling and reliability after storage, plastic materials must be compatible with propellant materials.

Two aspects of compatibility must be considered. The plastic must not react with the propellant, creating a more sensitive or degraded product. Similarly, the propellant must not attack the plastic, resulting in degradation of the physical properties of the plastic. Thermal analysis is one of the analytical test techniques useful in evaluating the stability of a propellant exposed to a plastic material during the operational life of a munition.

The test program described in this report was performed using thermal analysis techniques to evaluate the compatibility of propellants M-26, PYRO and NACO with a variety of plastic adhesives and foams. The data generated give a statistical measure of propellant stability during aging in contact with the plastics. No data were generated regarding the effect of the propellant on the plastic materials.

II. SUMMARY

The objective of this program was to evaluate the stability of several propellants when aged in contact with plastic adhesives and foams. These data are required for application to Navy gun propulsion technology.

There are several tests useful in determining incompatibility in propellant-plastic mixtures. Rogers[1] has proposed the use of a thermal initiation test to determine short-term thermal instability. This technique is a modification of the older Henkin test[2]. Long-term aging stability has been predicted principally by use of the vacuum stability test[3, 4] that predicts compatibility by measuring gas evolution of the propellant-plastic system when aged at elevated temperatures. Variations of the vacuum stability test include Taliani, modified Taliani, and witness tests. These variations are primarily concerned with differences in recording and/or analyzing data.

The modified Henkin test is not useful for predicting long-term aging stability. The vacuum stability test will indicate short-term aging instability, although the results must be interpreted noting that typically only one test temperature is used. Several limitations should be noted concerning use of the vacuum stability test to determine long-term stability.

First, the test is not readily adaptable to quantitative analysis. In the typical vacuum stability test, as performed by Picatinny Arsenal[4], a net increase of five milliliters in the amount of gas given off by five grams of propellant (due to exposure to the plastic) is considered evidence of excessive reactivity. The Naval Ordnance Laboratories have established four stability classes for the same test (see Table I). They determined each class by the volume of gas evolved per gram propellant after 48 hours at 100°C [(milliliters of gas measured at standard temperature and pressure (STP)].

Table I. Classification of Propellants by the 100°C Vacuum Stability Test[5]

Class	Milliliters of gas/gram/ 48 hours/STP	Quality
I	0-2	Satisfactory Stability
II	2-6	Borderline Stability
III	6-18	Unstable
IV	Over 18	Extremely Unstable, Possibly Hazardous

Evolution of additional gas* is attributed to undesirable interaction between the propellant and the plastic, or undesirable reactions induced by the polymer[4]. The gas evolution criterion, to be quantitatively useful, must be correlated with long-term aging tests on each propellant-plastic system. This, of course, is desirable regardless of the technique; still, it is not completely practical considering the large number of propellants and plastics available. To be of practical value, a test technique should yield data that will allow a kinetic analysis to predict aging stability.

The second limitation of the vacuum stability test is that the polymers are generally tested in the solid phase (thermoplastic or cured thermoset). In many end use applications, it is desirable to cure the plastic in contact with the propellant. This may create a system that is very unstable during cure of the polymer, but is compatible after the polymer is fully cured. This problem can be overcome by testing the vacuum stability of each of the plastic components (resin, curing agent, catalyst, filler, etc.) with the propellant and then testing the resulting cured system. Unfortunately, in some cases, this technique does not duplicate the environment experienced by the propellant, and it also markedly increases the test time.

Thermal analysis test techniques such as Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC), and Effluent Gas Analysis (EGA) can be used to determine short-term thermal instability and to predict long-term aging stability. Quantitative predictions of long-term aging stability can be made by applying one of several kinetic interpretations to the data. Both the fully cured polymer and the polymer curing against the propellant can be tested.

Thermal analysis techniques measure enthalpic effects attendant in most chemical or physical changes that occur within a material as the environmental temperature is increased at a selected rate. During a thermal analysis test, the temperature of the sample is compared with the temperature of a reference material while both are heated at a controlled rate. The results are normally plotted as temperature difference versus reference termperature. DSC combines the DTA method of temperature comparison with closed-loop heat compensation. The measurement plotted is the electrical energy in calories per second required to maintain the sample and reference at the same temperature. The results plotted show endothermic and exothermic peaks whose areas are directly proportional to the energy absorbed or liberated by the sample. EGA measures the relative quantity of gas evolved by the sample as the environmental temperature is increased at a selected rate.

*Additional gas refers to the quantity of gas evolved in excess of that evolved by propellant and plastic when separately exposed to 48 hours at 100°C.

In using thermal analysis to evaluate the compatibility of propellant-plastic combinations, the assumption is made that either sample temperature or gas evolution is maximum at the peak reaction rate. This assumption is well founded for propellants and explosives as indicated by Cook[5].

III. DISCUSSION

Compatibility of the test plastics with various gun propellants was examined by thermal analysis techniques, primarily Differential Scanning Calorimetry.

Compatibility testing by thermal analysis examines the kinetics of the thermal decomposition reaction. The compatibility of a material is determined by the effect exposure to the material has on the decomposition reaction kinetics of the explosive or propellant.

It should be noted that these tests make no inferences as to the chemistry of the decomposition reaction or to the effect of the propellants on the test plastics.

Activation energy and frequency factor of the decomposition reaction were determined by the variable heating rate method as developed by Kissinger[6] and modified by Pakulak[7].

The reaction kinetics as described by Kissinger are based upon first order reaction rates. Assuming a first order reaction rate, an explosive will degrade as follows:

$$\left(\frac{\partial x}{\partial t}\right)_T = k_T \, (1-x) \qquad (1)$$

where x = the fraction of the explosive degraded

t = time

k = the reaction rate constant at temperature (T).

The reaction rate constant is determined from the Arrhenius Rate Equation

$$k_{(T)} = A \, \exp \, (-E/RT) \qquad (2)$$

where A = frequency factor

E = activation energy

R = gas constant (1.987 calories/mole°K)

T = temperature in degrees Kelvin.

When the temperature is changing, as in a Differential Scanning Calorimeter run, the reaction rate becomes

$$\frac{dx}{dt} = \left(\frac{\partial x}{\partial t}\right)_T + \left(\frac{\partial x}{\partial T}\right)_t \frac{dT}{dt} \qquad (3)$$

By determining X and T at the same instant, the time coordinate $\left(\frac{\partial x}{\partial T}\right)_t$ becomes zero. This reduces the rate equation to

$$\frac{dx}{dt} = A(1-x)\exp(-E/RT) \qquad (4)$$

When the reaction is occurring at its maximum rate, its derivative with respect to time becomes zero. Solving for $\left(\frac{d}{dt}\right)\left(\frac{dx}{dt}\right)$, the equation becomes:

$$\frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{dx}{dt}\left(\frac{E}{RT^2} \frac{dT}{dt}\right) = A\exp(-E/RT) \qquad (5)$$

The temperature at which a reaction occurs at its maximum rate, dx/dt, can be measured as the peak exotherm temperature of a DSC thermogram. Therefore, the maximum reaction rate is defined as

$$A\exp(-E/RT_m) = \left(\frac{E}{RT_m^2}\right) \frac{dT}{dt} \qquad (6)$$

where T_m is the peak temperature of a DSC trace. This equation reduces to the relationship

$$\frac{d\left(\ell n \frac{\varphi}{T_m^2}\right)}{d\left(\frac{1}{T_m}\right)} = -\frac{E}{R} \qquad (7)$$

where φ is the change in temperature with respect to time dT/dt or the sample heating rate.

The peak exotherms and heating rates from a series of DSC tests can be used to solve for the activation energy by Equation (7). Using this value for E, the frequency fact, A, can be determined by Equation (6). With the values of E and A determined, the rate constant, K, can be determined by using the Arrhenius Rate Equation, (2).

There are a number of assumptions necessary in making a prediction of kinetic data from thermal analysis data.

1. It is assumed that the decomposition by-products are a combination of gaseous and solid nonexplosive materials, free to escape without pressure buildup. An isothermal increase in pressure due to trapped gases would affect the decomposition reaction. It should be noted that the vacuum stability test is dependent on the formation of gaseous by-products for a prediction of stability. Thermal decomposition of explosives has been discussed by several authors, including Gray and Bonomo[8] and Dacons, et al[9].

2. It is assumed that thermal decomposition values are comparable for the explosive in the melt, solid and vapor phases. This assumption is incorrect, but the difference in the decomposition rate for the two phases is not generally known. Various authors claim that the decomposition rates may be as much as 50 to 100 times faster in the melt phases than in the solid phases. For example, Gray and Bonomo[9] have stated that production of TNT decomposition by-products is dependent on temperature, the greatest decomposition occurring between 150° and 160°F (the highest temperature studied in their work). The difference is, of course, due to the greater mobility of the atoms involved in the decomposition when the explosive is in the liquid phase (above its melting temperature). Several authors, including Farmer[10] and Rosen[11], have discussed this area.

The techniques used for deriving the reaction kinetics from thermal analysis data are subject to much discussion. Reed, et al,[12] have argued that Kissinger's attempt to prove that the maximum reaction rate occurs at the peak of the DTA curve is incorrect. They note, additionally, that regardless of the proof, large errors in the calculated value of E can occur in systems when the maximum reaction rates are within 1°C (experimental error) of the peak temperature. Mastin[13], in a theoretical study, has compared Kissinger's method with the modification used by Pakulak. In Kissinger's original method, the actual sample temperature at the peak differential temperature is used in Equation (7). The modified formula involves the use of the reference temperature at the maximum reaction rate. Mastin[13] concludes that the Kissinger method will give reasonably good kinetic rate parameters in a simple decomposition reaction. He notes that the greatest error occurs at fast heating rates when it is assumed that the rate of change of the sample temperature at the maximum reaction rate is equal to the apparatus heating rate.

With a temperature-compensating design, as in the Perkin-Elmer DSC apparatus, this problem is diminished; however, thermal gradients within the sample are still a source of possible error. For this reason, sample sizes are kept to a minimum.

Given the processing conditions (the time at which the system will be held at the processing temperature), an arbitrary criterion can be established for short-term thermal stability. For example, such a criterion might require that the presence of test material with the explosive increase the amount of explosive reacted by less than one-tenth of one percent.

It is somewhat more difficult to establish a criterion for long-term aging stability because of the unknowns in storage time and temperature. In this case, a safe criterion would require that there be no significant increase in the decomposition rate due to the presence of the test material. This requirement dictates that the activation energy and frequency factor for the propellant only be compared with the same kinetic parameters for the propellant exposed to the plastic. Using the Arrhenius Rate Equation, predictions may be made as to the life of test and control samples. If these predictions are statistically similar, the system is compatible.

IV. TECHNICAL APPROACH

All testing was performed with a Perkin-Elmer model DSC-1B Differential Scanning Calorimeter. Sample preparation was as follows:

> Samples weighing approximately 5 milligrams were cut from each of the propellants and run as controls. Then similar samples were run in contact with each of the various test plastics. With the liquid plastic samples, the propellant sample was coated and allowed to dry. With the solid and foam samples, the plastic was either cut into thin slices or ground to a powder and mixed with the propellant sample. The samples were placed into aluminum sample pans with an aluminum cover crimped over the top of the sample. The sample pans were placed in the DSC sample cells and covered with an aluminum dome. The temperature at which the decomposition rate reached its maximum, the peak exotherm on the DSC thermogram (Figure 1), was then recorded.

Due to nonlinearities in thermocouple output, the indicated temperature and the actual temperature of a DSC cell may not be the same across the entire temperature range of the instrument. Because of the need for precise temperature accuracy, it was necessary to calibrate the DSC apparatus. This was done by determining the indicated melt points of known standards across the entire temperature range and at each of the test heating rates. This operation was performed twice, first prior to the initial series of testing and again prior to a series of requested retests on some of the data. The calibration data is listed in Table II. The temperature correction data at each heating rate was found to be a second order curve. The coordinates of these curves were calculated to a least squares fit by computer and placed in a FORTRAN program that corrected the temperature error of the DSC runs and printed this data into data files. This program is listed in Appendix A as Corect—Temperature Correction Program.

The corrected data from each propellant and propellant-plastic combination was then run through a second FORTRAN program to calculate the activation energy, frequency factor, and reaction rate constant at any desired temperature. This program will also predict the extent of the decomposition reaction over any desired period of time at any desired temperature. This is an extrapolation of data over several magnitudes of time via an Arrhenius Rate Equation, which must be remembered when the predicted service lifes are examined. This program is listed in Appendix A as Energy—Activation Energy Program.

One criterion for judging a plastic to be compatible with a propellant was that there be no statistically significant difference between the control and test sets of data. All statistical analysis was performed at 95 and 99 percent confidence levels.

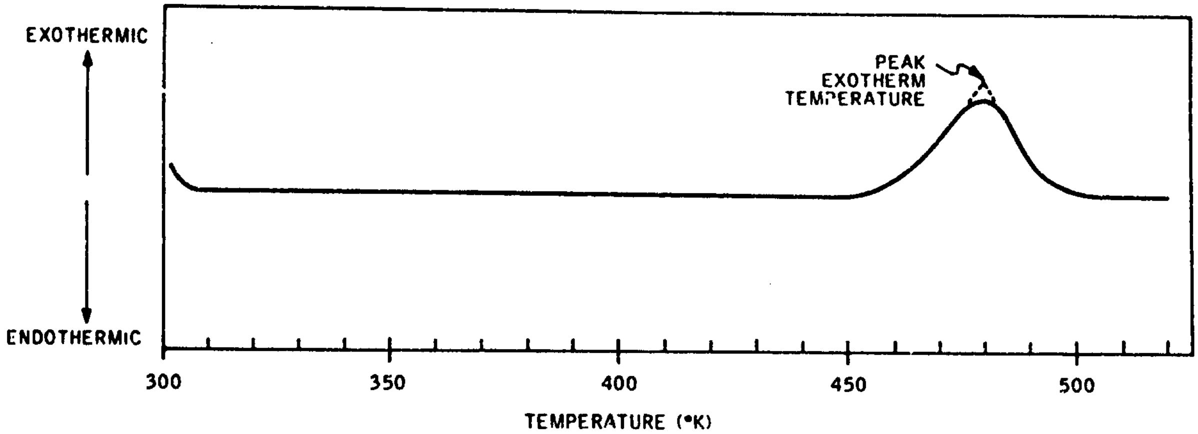

Figure 1. Typical DSC Thermogram

Table II. DSC Calibration

MATERIAL	TRUE MELT POINT (°K)	INDICATED MELT POINT (°K) AT HEATING RATE (°C/MINUTE) OF						
		80	40	20	10	5	2.5	1.25
INITIAL TESTING - JULY 1972								
IODINE METAL	386.7	394.2	388.8	386.0	384.3	383.3	383.3	
INDIUM METAL	429.8	438.0	433.0	430.8	429.4	428.9	428.5	
AMMONIUM NITRATE	442.8	454.2	448.0	444.6	443.4	442.6	442.1	
EUTECTIC SOLDER	452.2	463.0	457.8	455.2	453.7	453.0	452.6	
TIN METAL	505.1	517.9	511.9	509.2	508.0	507.0	506.7	
LEAD	600.7	609.3	604.4	601.8	600.2	599.7	599.5	
RETESTING - FEBRUARY 1973								
NAPTHALENE	353.4	354.2	348.6	346.2	345.0	344.3	343.4	343.5
BENZOIC ACID	395.6	399.0	393.9	391.8	389.9	389.4	389.5	389.4
INDIUM METAL	429.8	436.0	430.8	427.8	426.3	425.6	425.2	425.5
2-CHLOROANTHRAQUINONE	482.1	489.1	483.0	481.4	480.2	479.4	479.4	479.8
TIN METAL	505.1	512.8	507.4	504.8	503.3	502.7	502.2	502.9
ANTHRAQUINONE	557.4	565.7	559.4	557.7	556.0	555.5	555.3	556.1
LEAD	600.7	605.4	600.7	598.2	596.3	595.4	595.1	596.0

The first test was an analysis to determine if the plot of $1/T$ versus log φ/T^2, from which the activation energy was calculated, was a fit to a straight line. This was done by the FORTRAN program listed in Appendix A as PROG1—Statistical Analysis - Program 1.

The second program, listed as PROG2—Statistical Analysis - Program 2, was used to compare the control and test data for each propellant-plastic combination. This program performed three tests. First, it determined if the variances in each data set were comparable. Second, it determined if the plots of $1/T$ versus log φ/T^2 for both the control and test sets of data were parallel. Third, it determined if the two plots were coincidental.

Each of these statistical programs must be satisfied in order that meaningful statements may be made regarding the compatibility of a given propellant-plastic combination.

The plot of $1/T$ versus log φ/T^2 measures the order of the reaction. If this plot fails to fit a straight line, the assumption that the reaction kinetics are first order is incorrect. None of the propellants evaluated failed this test.

Homogeneity of the sample variances is determined to test the assumption that the sample data comes from the same population. The statistical technique used to compare the parallelism and contingency of two sets of data (propellant only versus propellant-plastic combination) is dependent upon whether or not the variances are equal.

The condition of two sets of data being parallel determines whether or not exposure of the propellant to the plastic has significantly changed the activation energy of the propellant decomposition reaction. Under normal circumstances, the plastic will not change the activation energy of the propellant regardless of compatibility. When it occurs, a change in activation energy may indicate an incompatible propellant-plastic combination.

The condition of two sets of data being contingent determines whether exposure of the propellant to the plastic has significantly changed the frequency factor of the propellant decomposition reaction. Under normal circumstances, for a propellant-plastic combination that is not compatible the activation energy will not be changed (the lines will be parallel), but the frequency factor will be significantly increased (the lines will not be contingent). In the event of the frequency factor decreasing, it may be said that there is interaction between the plastic and propellant, but the result is not such that a degraded or hazardous propellant will result.

The results of the testing list any plastic-propellant combination that passed all of the tests as compatible. If a plastic-propellant combination failed at one confidence level and passed at the other, or failed any of the statistical tests at both confidence levels it was analyzed further by reviewing the shelf rediction obtained from the Arrhenius Rate Equation. Only in the case wn a plastic-propellant combination failed the statistical tests and indicated a lar change in shelf life was the system considered incompatible.

V. RESULTS AND CONCLUSIONS

The results of the DSC tests on each propellant and propellant-plastic combination are included in Appendix B. The temperatures listed are the corrected values. Included are the predictions for the percent of propellant unreacted when stored for 1, 2, 5, 10, and 20 years at 25°, 50°, 75°, and 100°C (298°, 323°, 348°, and 373°K). Also attached are the plots of $1/T$ versus Φ/T^2 for control and propellant-plastic combination.

Table III lists the results of the statistical analysis of the test data.

The data fits on NACO and PYRO control and plastic-propellant combinations were very good. The data for M-26 was much more scattered. For this reason, the limits for statistical noninteraction for M-26 tended to be quite broad, whereas the limits for the other propellants were more exacting. This accounts for the fact that some of the M-26 plastic combinations did not statiscally interact, while their plots seemed to be more divergent than some of the other propellant-plastic combinations where statistical interaction was noted.

Several combinations are noted where statistical propellant-plastic interactions are noted. Reviewing the shelf-life predictions for each of these combination yields two examples of the plastic having a significant effect on the propellant. In each instance, the data would appear to suggest greater stability for the propellant due to exposure to the plastic. It is concluded that regardless of the effect predicted by extrapolation with the Arrenius Rate Equation the systems have demonstrated a large chemical interaction that could be deleterious to device performance. For this reason M-26 with EC 1099 and PYRO with Ultrabond 76-125 are considered incompatible. In all other cases, the combinations are judged compatible.

Compatibility data was requested on Celcon 1011 with M-26 propellant. Considerable difficulty was experienced in attempting to achieve good DSC data due to melting of the Celcon prior to the decomposition of M-26. As an alternative approach, the Effluent Gas Analysis (EGA) accessory to the DSC was used in an attempt to determine the M-26 decomposition temperatures. EGA measures the relative quantities of gas output of a sample during a DSC run. Assuming that the peak decomposition temperature and the temperature at which peak gas evolution occurs are the same, EGA data should coincide with DSC data.

During the initial EGA testing with M-26 and Celcon, two problems were encountered. First, a short time lag exists between the evolution of the gas output of the sample and its detection by the EGA detector. This is due to time required for the gas to pass from the sample cell through a line to the EGA detector. Secondly, the EGA is presently set up to operate with nitrogen as a carrier gas. The use of a nitrogen atmosphere rather than air causes some changes in the decomposition characteristics of the M-26 propellant. These problems could be eliminated for future testing by careful calibration of the EGA time lag and conversion to air as a carrier gas.

Table III. Statistical Analysis Results

TEST SAMPLE	ACTIVATION ENERGY (KCAL/MOLE)	FREQUENCY FACTOR	PROG ONE	VARIANCES	PARALLEL	COINCIDENT	RATING
M-26 CONTROL	49.3	0.75×10^{21}	P	---	---	---	
M-26/GUN PLUG FOAM	53.9	0.11×10^{24}	P	P	P	P	COMPATIBLE
M-26/GUN PLUG FOAM (HUMIDITY)	54.6	0.27×10^{24}	P	P	P	P	COMPATIBLE
M-26/LOCTITE A	49.8	0.15×10^{22}	P	P	P	P	COMPATIBLE
M-26/LOCTITE N	47.4	0.10×10^{21}	P	P	P	P	COMPATIBLE
M-26/EC 1099	59.6	0.81×10^{26}	P	P	P	F	INCOMPATIBLE
M-26/UNFILLED CARTRIDGE CASE	49.7	0.10×10^{22}	P	P	P	P	COMPATIBLE
M-26/FILLED CARTRIDGE CASE	47.7	0.12×10^{21}	P	P	P	P	COMPATIBLE
PYRO CONTROL	44.4	0.19×10^{19}	P	---	---	---	
PYRO/UNFILLED CARTRIDGE CASE	45.8	0.93×10^{19}	P	P	M	M	COMPATIBLE
PYRO/FILLED CARTRIDGE CASE	44.6	0.26×10^{19}	P	P	P	P	COMPATIBLE
PYRO/ULTRABOND 76-125	52.6	0.20×10^{23}	P	P	M	M	INCOMPATIBLE
PYRO/EC 1099	46.6	0.25×10^{20}	P	P	P	F	COMPATIBLE
NACO CONTROL	47.4	0.64×10^{20}	P	---	---	---	
NACO/EC 1099	43.7	0.13×10^{19}	P	P	M	M	COMPATIBLE
NACO/ULTRABOND 76-125	44.6	0.36×10^{19}	P	P	P	P	COMPATIBLE

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APPENDIX A
COMPUTER PROGRAMS

Compatibility Analysis of Thermal Data

DSC DATA

↓

CORECT - FORTRAN
COMPARES RAW DATA TO CALIBRATION DATA;
CORRECTS TEMPERATURE READOUT ERROR

↓

ENERGY - FORTRAN
PERFORMS ACTIVATION ENERGY AND
FREQUENCY FACTOR CALCULATIONS; WILL
ALSO MAKE ROUGH SHELF-LIFE PREDICTIONS

↓

PROG 1 - FORTRAN
DETERMINES IF 1/T VERSUS Φ/T^2 DATA IS
A STATISTICAL FIT TO A STRAIGHT LINE

↓

PROG 2 - FORTRAN
COMPARES TWO LINES; DETERMINES IF DATA
VARIANCES ARE STATISTICALLY COMPARABLE,
DETERMINES IF LINES ARE STATISTICALLY
PARALLEL, DETERMINES IF LINES ARE
STATISTICALLY COINCIDENT

CORECT

FORTRAN -DSC TEMPERATURE CORRECTION

```
10 DIMENSION NAM(6),PARAM(8),A(3,8),P(8),TEMP(7),INDEX(25),T(25,7)
20 +,IFOR(14),MFOR(7)
30 DATA PARAM/80.,40.,20.,10.,5.,2.5,1.25,.625/,A/.358917E-3,
40 +.630512,83.0581,.302724E-3,.689625,73.1862,.294814E-3,.698029
50 +,73.7081,.32965E-3,.664192,83.1491,.296576E-3,.697677,75.5256
60 +,.293012E-3,.700064,75.5849,0.,1.,0.,0.,1.,0./
70 +,IFOR/'(I','4,','1H',',,','F7','.3',', ',' 7','(1','H,',
80 +',F','7.','2)',' )'/,MFOR/' 1',' 2',' 3',' 4',' 5',' 6',' 7'/
90 WRITE(9,10)
100 10 FORMAT(/'NAME OF INPUT DATA FILE')
110 READ(9,20)NAM
120 20 FORMAT(6A2)
130 CALL DEFINE(1,NAM)
140 WRITE(9,30)
150 30 FORMAT(/'NAME OF DATA OUTPUT FILE')
160 READ(9,20)NAM
170 CALL DEFINE(2,NAM)
180 N=0
190 40 IF(IEOF(1).EQ.1)GOTO140
200 N=N+1
210 READ(1,50)LNO,P(N),TEMP
220 50 FORMAT(I5,8G10.0)
230 WRITE(9,60)P(N)
240 60 FORMAT(//'PHI:',F7.3/'MEASURED  CALCULATED')
250 DO 70 I=1,8
260 IF(PARAM(I)-P(N))70,80,70
270 70 CONTINUE
280 STOP PHI NOT IN LIST
290 80 DO 90 J=1,7
300 IF(TEMP(J))100,100,90
310 90 CONTINUE
320 J=8
325 100 J=J-1
330 INDEX(N)=J
340 DO 120 K=1,J
350 T(N,K)=A(1,I)
360 DO 110 L=1,2
370 110 T(N,K)=T(N,K)*TEMP(K)+A(L+1,I)
380 120 WRITE(9,130)TEMP(K),T(N,K)
390 130 FORMAT(F8.2,F12.2)
400 GOTO40
410 140 LNC=1
420 WRITE(2,150)LNO,N
430 150 FORMAT(I4,1H,,I4)
440 DO 160 I=1,N
450 LNO=LNO+1
460 J=INDEX(I)
470 IFOR(8)=MFOR(J)
480 160 WRITE(2,IFOR)LNO,P(I),(T(I,K),K=1,J)
490 STOP SAVE YOUR FILE
500 END
```

ENERGY

FORTRAN - ACTIVATION ENERGY PROGRAM

```
COMMON X(50,2),Y(50),A(2,2),U(7),C(50),T(9),AK(9),Z(9)
+, Q(9),B(2),DEG(9),NAM(6),AKI(9),EX(50),WYE(50)
DOUBLE PRECISION X,Y,A,C,AK,Q,B,YOU,DVEE,EO,E,R,D,ZEE
+,TEE,EFF,F,S1,S2,S3,EL,DF,P
COMPLEX RATIO
RATIO='INFINITE'
WRITE(9,10)
10 FORMAT(/'WANT DATA FILE DESCRIPTION? (YES OR NO)')
READ(9,20)IWANT
20 FORMAT(6A2)
IF(IWANT.EQ.2HNO)GOTO40
WRITE(9,30)
30 FORMAT(/'THIS PROGRAM FITS A 1-ST DEGREE POLYNOMIAL TO A BIVARI'
+ 'ATE'/'SET OF DATA, AND PRINTS A SUMMARY OF THE FIT.'/'THE'
+ ' DATA IS READ FROM A FILE WHICH MUST BE PREPARED PRIOR '
+ 'TO EXECUTION.'/'THE DATA FILE SHOULD BE SET UP AS FOLLOWS:'//
+ 'LINE 1:  LINE NO,M'/'LINE 2:  LINE NO,V1,U1,U2,U3,U4,U5,U6,U7'/
+ 'LINE 3:  LINE NO,V2,U1,U2,U3,U4,U5,U6,U7'/'.........ETC'
+ ' UNTIL ALL V-U DATA SETS HAVE BEEN ENTERED'/'WHERE M IS '
+ 'THE NUMBER OF V,U DATA SETS,'/'VN IS A HEATING RATE IN '
+'DEGREES C. PER MIN. '/'AND EACH UN IS A TEMPERATURE IN DEGREES '
+ 'KELVIN'/' OBSERVED AT THE HEATING RATE VN.'/
+'UP TO 7 TEMPERATURES MAY BE USED FOR 1 HEATING RATE.'/
+ 'EACH LINE OF THE DATA FILE MUST BEGIN '
+ 'WITH A LINE NUMBER'/'FOLLOWED BY A COMMA.'//'EACH ENTRY '
+ 'EXCEPT THE LAST ON ANY LINE SHOULD BE FOLLOWED BY A COMMA.'//
+ 'FOLLOW THE ABOVE DATA WITH LINES CONTAINING'/'(IN ADDITION'
+ ' TO THE LINE NUMBER):'/
+ ' A) THE NUMBER OF STORAGE TEMPERATURES. (ZERO IF NONE.)'/
+ '    *IGNORE STEPS B,C,D,AND E IF THE NUMBER ABOVE IS 0.**'/
+ ' B) THE PARTICULAR STORAGE TEMPERATURES (DEGREES KELVIN)'/
+ ' C) THE NUMBER OF VALUES FOLLOWING (ZERO IF NONE.)'/
+ ' D) EITHER C1/C0 OR TIME, WHICHEVER IS TO BE SOLVED FOR.'/
+ ' E) PARAMETER VALUES FOR TIME (YEARS), OR C1/C0 (PERCENT)'
+ /'     -DEPENDING UPON WHAT WORD WAS TYPED FOR PART D.'//)
STOP
40 WRITE(9,50)
50 FORMAT(/'NAME OF INPUT DATA FILE')
READ(9,20)NAM
CALL DEFINE(1,NAM)
WRITE(9,70)
70 FORMAT(/'NAME OF OUTPUT DATA FILE')
READ(9,20)NAM
CALL DEFINE(2,NAM)
LNO=0
READ(1,80)LNS,M
80 FORMAT(2I6)
S3=0.D0
WRITE(9,90)
90 FORMAT(//'INPUT DATA'/' PHI     TEMP'9X'1/T'11X'PHI/TSQUARE')
```

ENERGY

FORTRAN - ACTIVATION ENERGY PROGRAM

```
10 COMMON X(50,2),Y(50),A(2,2),U(7),C(50),T(9),AK(9),Z(9)
20 +, Q(9),B(2),DEG(9),NAM(6),AKI(9),EX(50),WYE(50)
30 DOUBLE PRECISION X,Y,A,C,AK,Q,B,YOU,DVEE,EO,E,R,D,ZEE
40 +,TEE,EFF,F,S1,S2,S3,EL,DF,P
50 COMPLEX RATIO
60 RATIO='INFINITE'
70 WRITE(9,10)
80 10 FORMAT(/'WANT DATA FILE DESCRIPTION? (YES OR NO)')
90 READ(9,20)IWANT
100 20 FORMAT(6A2)
110 IF(IWANT.EQ.2HNO)GOTO40
120 WRITE(9,30)
130 30 FORMAT(/'THIS PROGRAM FITS A 1-ST DEGREE POLYNOMIAL TO A BIVARI'
140 + 'ATE'/'SET OF DATA, AND PRINTS A SUMMARY OF THE FIT.'/'THE'
150 + ' DATA IS READ FROM A FILE WHICH MUST BE PREPARED PRIOR '
160 + 'TO EXECUTION.'/'THE DATA FILE SHOULD BE SET UP AS FOLLOWS:'//
170 + 'LINE 1:  LINE NO,M'/'LINE 2:  LINE NO,V1,U1,U2,U3,U4,U5,U6,U7'/
180 + 'LINE 3:  LINE NO,V2,U1,U2,U3,U4,U5,U6,U7'/'.........ETC'
190 + ' UNTIL ALL V-U DATA SETS HAVE BEEN ENTERED'/'WHERE M IS '
200 + 'THE NUMBER OF V,U DATA SETS,'/'VN IS A HEATING RATE IN '
210 +'DEGREES C. PER MIN.,'/'AND EACH UN IS A TEMPERATURE IN DEGREES '
220 + 'KELVIN'/' OBSERVED AT THE HEATING RATE VN.'/
230 +'UP TO 7 TEMPERATURES MAY BE USED FOR 1 HEATING RATE.'/
240 + 'EACH LINE OF THE DATA FILE MUST BEGIN '
250 + 'WITH A LINE NUMBER'/'FOLLOWED BY A COMMA.'//'EACH ENTRY '
260 + 'EXCEPT THE LAST ON ANY LINE SHOULD BE FOLLOWED BY A COMMA.'//
270 + 'FOLLOW THE ABOVE DATA WITH LINES CONTAINING'/'(IN ADDITION'
280 + ' TO THE LINE NUMBER):'/
290 + ' A) THE NUMBER OF STORAGE TEMPERATURES. (ZERO IF NONE.)'/
300 + '    *IGNORE STEPS B,C,D,AND E IF THE NUMBER ABOVE IS 0.**'/
310 + ' B) THE PARTICULAR STORAGE TEMPERATURES (DEGREES KELVIN)'/
320 + ' C) THE NUMBER OF VALUES FOLLOWING (ZERO IF NONE.)'/
330 + ' D) EITHER C1/CO OR TIME, WHICHEVER IS TO BE SOLVED FOR.'/
340 + ' E) PARAMETER VALUES FOR TIME (YEARS), OR C1/CO (PERCENT)'
350 + /'    -DEPENDING UPON WHAT WORD WAS TYPED FOR PART D.'//)
360 STOP
370 40 WRITE(9,50)
380 50 FORMAT(/'NAME OF INPUT DATA FILE')
390 READ(9,20)NAM
400 CALL DEFINE(1,NAM)
410 WRITE(9,70)
420 70 FORMAT(/'NAME OF OUTPUT DATA FILE')
430 READ(9,20)NAM
440 CALL DEFINE(2,NAM)
450 LNO=0
460 READ(1,80)LNS,M
470 80 FORMAT(2I6)
480 S3=0.DO
490 WRITE(9,90)
500 90 FORMAT(//'INPUT DATA'/' PHI    TEMP'9X'1/T'11X'PHI/TSQUARE')
```

```
L=0
DO 130 I=1,M
READ(1,100)LNS,VEE,U
100 FORMAT(I5,8G10.0)
DO 130 J=1,7
IF(U(J))130,130,110
110 L=L+1
EX(L)=1./U(J)
WYE(L)=VEE/(U(J)**2)
YOU=U(J)
DVEE=VEE
X(L,1)=1.D0
X(L,2)=1.D0/YOU
WRITE(9,120)VEE,U(J),EX(L),WYE(L)
120 FORMAT(F7.2,F8.2,2E14.4)
Y(L)=DLOG(DVEE/(YOU**2))/DLOG(10.D0)
WYE(L)=Y(L)
S3=S3+Y(L)**2
130 CONTINUE
LNO=LNO+1
WRITE(2,140)LNO,L
140 FORMAT(I4,1H,,I4)
DO 150 I=1,L
LNO=LNO+1
150 WRITE(2,160)LNO,EX(I),WYE(I)
160 FORMAT(I4,2(1H,,E14.6))
N=2
DO220 I=1,N
DO 200 J=1,N
A(I,J)=0.D0
DO 180 K=1,L
180 A(I,J)=A(I,J)+X(K,I)*X(K,J)
IF (I.EQ.1)GOTO 200
LNO=LNO+1
AIJ=A(I,J)
WRITE (2,190)LNO,AIJ
190 FORMAT(I4,1H,,E14.6)
200 CONTINUE
B(I)=0.D0
DO 210 K=1,L
210 B(I)=B(I)+X(K,I)*Y(K)
LNO=LNO+1
BI=B(I)
220 WRITE (2,190)LNO,BI
LNO=LNO+1
ESS=S3
WRITE (2,190)LNO,ESS
DO 250 K=1,N
P=A(K,K)
DO 230 J=K,N
230 A(K,J)=A(K,J)/P
B(K)=B(K)/P
DO 250 I=1,N
IF (I.EQ.K) GO TO 250
F=A(I,K)
```

```
DO 240 J=K,N
240 A(I,J)=A(I,J)-F*A(K,J)
B(I)=B(I)-F*B(K)
250 CONTINUE
WRITE(9,260)
260 FORMAT( ///'LEAST SQUARES SOLUTION COEFFICIENTS ARE:'/)
DO 280 I=1,N
IM1=I-1
BI=B(I)
WRITE(9,270)IM1,BI
270 FORMAT( '    A(',I3,') = ',E15.7)
LNO=LNO+1
280 WRITE (2,190)LNO,BI
WRITE(9,290)
290 FORMAT(//'POLYNOMIAL CURVE FIT OF DEGREE   1'//
+ 3X'X-ACTUAL'7X'Y-ACTUAL'7X'Y-CALC'9X'DIFF'9X'PCT-DIFF'/)
S1=0.D0
S2=0.D0
DO 330 I=1,L
C(I)=B(N)*X(I,2)+B(N-1)
D=Y(I)-C(I)
S1=S1+D
S2=S2+D*D
CEE=C(I)
DEE=D
IF( C(I).EQ.0.D0) GO TO 310
OUT=100.D0*D/C(I)
WRITE(9,300)EX(I),WYE(I),CEE,DEE,OUT
300 FORMAT(E13.6,3E15.6,F11.1)
GOTO330
310 WRITE(9,320)EX(I),WYE(I),CEE,DEE,RATIO
320 FORMAT(E13.6,3E15.6,3X,4A2)
330 CONTINUE
EL=L
EST=S1/EL
WRITE(9,340)EST
340 FORMAT(//'MEAN ERROR OF ESTIMATE FOR Y = ',E14.6)
IF( L-2.NE.0)GOTO 360
WRITE(9,350)
350 FORMAT( 'NUMBER OF POINTS EQUALS DEGREE MINUS ONE'/
+ 'CURVE FIT IS SOLTUION OF SIMULTANEOUS EQUATIONS'/
+ 'STANDARD ERROR DOES NOT APPLY')
GO TO 380
360 DF=L-2
STERR=DSQRT(S2/DF)
WRITE(9,370)STERR
370 FORMAT('UNBIASED STANDARD ERROR OF'/'ESTIMATE FOR Y:'
+,16X,E14.6)
LNO=LNO+1
ESS=S2
WRITE(2,190)LNO,ESS
380 R=1.987D0
E0=-DLOG(10.D0)*R*B(2)*1.D-3
E=-DLOG(10.D0)*B(2)
WRITE(9,390)
```

```
390 FORMAT(/'CALCULATED'/3X,'1/T      '7X'PHI/TSQUARE')
DO 400 I=1,L
F=DEXP(C(I)*DLOG(10.DO))
IF(I.EQ.L)EFF=F
FF=F
400 WRITE(9,300)EX(I),FF
D=DEXP(E*X(L,2))*EFF*E/60.DO
EEO=EO
DEE=D
WRITE(9,410)EEO,DEE
410 FORMAT(//'E (KCAL/MOLE)'E14.6/'A (SEC-1)       ',E13.6)
READ(1,80)LNS,MO
IF(MO.EQ.0)GOTO 580
READ(1,100)LNS,(T(I),I=1,MO)
DO 420 I=1,MO
TEE=T(I)
AK(I)=D*DEXP(-E/TEE)
420 AKI(I)=AK(I)
READ(1,80)LNS,M1
IF(M1.EQ.0)GOTO540
READ(1,430)LNS,VARY
430 FORMAT(I5,2A2)
IF(VARY.NE.'TIME')WRITE(9,440)
440 FORMAT(/'DEGREES     K'8X'PER CENT, C1 OF CO, (TIME IN YEARS)')
 IF(VARY.EQ.'TIME')WRITE(9,460)
460 FORMAT(/'DEGREES     K'8X'TIME IN MINUTES, (C1/CO IN PERCENT)')
 470 FORMAT('KELVIN    (SEC -1)',6F8.1/)
READ (1,100)LNS,(Z(J),J=1,M1)
DO 490 J=1,M1
ZEE=Z(J)
IF(VARY.NE.'TIME') Q(J)=ZEE*365.DO*24.DO*3600.DO
IF(VARY.EQ.'TIME') Q(J)=DLOG(100.DO/ZEE)/60.DO
490 CONTINUE
WRITE(9,470)(Z(J),J=1,M1)
DO 520 I=1,MO
DO 510 J=1,M1
IF(VARY.EQ.'TIME')GOTO500
F=Q(J)*AK(I)
IF(F.GE.9.91)DEG(J)=0.
IF(F.LT.9.91DO)DEG(J)=100.DO*DEXP(-F)
GO TO 510
500 DEG(J)=Q(J)/AK(I)
510 CONTINUE
520 WRITE(9,530)T(I),AKI(I),(DEG(J),J=1,M1)
530 FORMAT(F7.1,E10.2,2X,6F8.2)
GO TO 580
540 WRITE(9,550)
550 FORMAT('DEGREES  K'/'KELVIN   (SEC-1)')
WRITE(9,560)(T(I),AKI(I),I=1,MO)
560 FORMAT(4(F7.1,E10.2))
580 WRITE(9,590)
590 FORMAT(///'[illegible] OUTPUT FILE')
STOP
END
```

PROG1
FORTRAN - STATISTICAL ANALYSIS - PROGRAM 1

```
10 DIMENSION NAM(6)
20 COMMON X(30),Y(30),N,EN,SX(2),SY(2),SXY(2),A,B(2),XBAR,YBAR
25 DOUBLE PRECISION X,Y,EN,SX,SY,SXY,A,B,XBAR,YBAR
30 WRITE(9,10)
40 10 FORMAT('NAME OF INPUT DATA FILE')
50 READ(9,20)NAM
60 20 FORMAT(6A2)
70 CALL DEFINE(1,NAM)
80 WRITE(9,30)
90 30 FORMAT(/' INPUT DATA'/4X'X',13X'Y')
100 READ(1,40)LNO,N
110 40 FORMAT(2I6)
170 DO 60 I=1,N
180 READ(1,50)LNO,X(I),Y(I)
190 50 FORMAT(I6,3D20.0)
191 EX=X(I)
192 EY=Y(I)
193 60 WRITE(9,70)EX,EY
200 READ(1,50)LNO,SY(1)
205 READ(1,50)LNO,SX(1)
210 READ(1,50)LNO,SX(2)
215 READ(1,50)LNO,SXY(1)
220 READ(1,50)LNO,SY(2)
225 READ(1,50)LNO,B(1)
230 READ(1,50)LNO,B(2)
235 READ(1,50)LNO,SXY(2)
260 70 FORMAT(2E14.6)
270 EN=N
280 YBAR=SY(1)/EN
290 A=YBAR
300 XBAR=SX(1)/EN
310 SXY(2)=SXY(2)/(EN-2.D0)
312 SA=A
314 SB=B(2)
316 SXBAR=XBAR
320 WRITE(9,80)SA,SB,SXBAR
330 80 FORMAT(/'Y=A+B(X-XBAR)'/'A:',E14.6/'B:',E14.6/'XBAR',E14.6)
341 IFRAT=1
342 90 FORMAT(I6,2G10.0)
350 DO 95 I=1,2
352 READ(1,90)LNO,CL,F2
360 95 CALL INDEP(I,CL,F2,IFRAT)
361 DO 110 I=1,2
362 READ(1,100)LNO,CL,T,CHISQ1,CHISQ2
364 100 FORMAT(I6,G10.0,3D10.0)
370 110 CALL CONLIM(I,CL,T,CHISQ1,CHISQ2)
380 STOP
390 END
1310 SUBROUTINE INDEP(I,CL,F,IFRAT)
1320 COMMON X(30),Y(30),N,EN,SX(2),SY(2),SXY(2),A,B(2),XBAR,YBAR
1325 DOUBLE PRECISION X,Y,EN,SX,SY,SXY,A,B,XBAR,YBAR
```

```
1330 DIMENSION SQS(3),IDF(3),DF(3),SQM(3)
1335 GOTO(5,35),I
1340 5 SQS(1)=(SXY(1)-SX(1)*SY(1)/EN)**2/(SX(2)-SX(1)**2/EN)
1350 IDF(1)=1
1360 DF(1)=IDF(1)
1370 SQM(1)=SQS(1)/DF(1)
1380 SQS(3)=SY(2)-SY(1)**2/EN
1390 IDF(3)=N-1
1400 SQS(2)=0.D0
1403 DO 7 IHOPE=1,N
1406 7 SQS(2)=SQS(2)+(Y(IHOPE)-(A+B(2)*(X(IHOPE)-XBAR)))**2
1410 IDF(2)=IDF(3)-IDF(1)
1420 DF(2)=IDF(2)
1430 SQM(2)=SQS(2)/DF(2)
1440 FRATIO=SQM(1)/SQM(2)
1450 WRITE(9,10)SQS(1),IDF(1),SQM(1),FRATIO
1460 10 FORMAT(/28HTEST FOR SLOPE EQUAL TO ZERO///38X,10HDEGREES OF/
1470 +23X49HSUM OF SQUARES  FREEDOM    MEAN SQUARE    F RATIO/
1480 +17HDUE TO REGRESSION 5X E14.6,I7,5X,E13.3,3X,F7.2)
1490 WRITE(9,20)SQS(2),IDF(2),SQM(2)
1500 20 FORMAT(8HRESIDUAL14XE14.6,I7,5X,E13.3)
1510 WRITE(9,30)SQS(3),IDF(3)
1520 30 FORMAT(/5HTOTAL17XE14.6,I7)
1530 35 WRITE(9,40)CL,IDF(1),IDF(2),F
1540 40 FORMAT(/2HATF5.1,12H % LEVEL AND,I3,1H,,I3,11H DEGREES OF
1550 +12H FREEDOM, F=,F8.3)
1560 IF(FRATIO.GT.F)GOTO60
1565 IFRAT=IFRAT+1
1570 WRITE(9,50)
1580 50 FORMAT(40HF RATIO LESS THAN F, CONSEQUENTLY CANNOT)
1590 60 WRITE(9,70)
1600 70 FORMAT(47HACCEPT THE HYPOTHESIS THAT Y IS DEPENDENT ON X.)
1610 RETURN
1620 END
1630 SUBROUTINE CONLIM(J,CL,T,CHISQ1,CHISQ2)
1650 COMMON X(30),Y(30),N,EN,SX(2),SY(2),SXY(2),A,B(2),XBAR,YBAR
1655 DOUBLE PRECISION X,Y,EN,SX,SY,SXY,A,B,XBAR,YBAR,VAR(3),
1656 +SDEV(3),T,CHISQ1,CHISQ2,ACOEFF,BCOEFF,XCOEFF,SX2,YC
1657 GOTO(5,155),J
1660 5 VAR(1)=(SX(2)-SX(1)**2/EN)/(EN-1.D0)
1670 VAR(2)=(SY(2)-SY(1)**2/EN)/(EN-1.D0)
1680 VAR(3)=(EN-1.D0)*(VAR(2)-B(2)*B(2)*VAR(1))/(EN-2.D0)
1690 DO 10 I=1,3
1700 10 SDEV(I)=DSQRT(VAR(I))
1710 WRITE(9,120)N
1720 WRITE(9,130)XBAR,SDEV(1),VAR(1)
1730 WRITE(9,140)YBAR,SDEV(2),VAR(2)
1740 WRITE(9,150)SDEV(3),VAR(3)
1750 120 FORMAT(/11HSAMPLE SIZE,I4//12HESTIMATES OF/23X4HMEAN,10X
1760 +5HSIGMA,9X,13HSIGMA SQUARED)
```

```
130 FORMAT(20HINDEPENDENT VARIABLE,3D14.6)
140 FORMAT(18HDEPENDENT VARIABLE,2X,3D14.6)
150 FORMAT(3HY.X,31X,2D14.6)
155 ACOEFF=T*SDEV(3)/DSQRT(EN)
ALOW=YBAR-ACOEFF
AHIGH=YBAR+ACOEFF
YB=YBAR
WRITE(9,160)CL,ALOW,YB,AHIGH
160 FORMAT(/F4.1,28H PER CENT CONFIDENCE LIMITS://9HPARAMETER,
+13X,11HLOWER LIMIT,3X,9HESTIMATED5X11HUPPER LIMIT,/
+16HINTERCEPT (YBAR),3X,3E14.6)
BCOEFF=T*SDEV(3)/(SDEV(1)*DSQRT(EN-1.DO))
BLOW=B(2)-BCOEFF
BHIGH=B(2)+BCOEFF
BEE=B(2)
WRITE(9,170)BLOW,BEE,BHIGH
170 FORMAT(5HSLOPE,14X,3E14.6)
SYX2LO=VAR(3)/CHISQ1
SYX2HI=VAR(3)/CHISQ2
VARYX=VAR(3)
WRITE(9,180)SYX2LO,VARYX,SYX2HI
180 FORMAT(19HSIGMA SQUARED (Y.X)3E14.6)
WRITE(9,190)CL
190FORMAT(/F5.1,41H % CONFIDENCE LIMITS FOR MEAN OF Y VALUES
+24H AT A PARTICULAR X VALUE//4X,1HX,13X,6HY CALC,8X,7HY UPPER
+7X,7HY LOWER)
ACOEFF=T*SDEV(3)
SX2=SX(2)-SX(1)**2/EN
DO 200 I=1,N
XCOEFF=X(I)-XBAR
YC=YBAR+B(2)*XCOEFF
YC1=DEXP(YC*DLOG(10.DO))
XCOEFF=DSQRT(1.DO/EN + XCOEFF**2/SX2)
YC2=DEXP((YC+ACOEFF*XCOEFF)*DLOG(10.DO))
YC3=DEXP((YC-ACOEFF*XCOEFF)*DLOG(10.DO))
EX=X(I)
200 WRITE(9,210)EX,YC1,YC2,YC3
210 FORMAT(4E14.6)
RETURN
END
```

PROG2

STATISTICAL ANALYSIS - PROGRAM 2

```
10 DIMENSION NAM(6),N(3),IFRAT(2),ITRAT(2,2)
20 DOUBLE PRECISION EN(3),X(2,50),Y(2,50),SX(3,2),SY(3,2)
30 +,SXY(3,2),XBAR(3),YBAR(3),VARX(3),VARY(3),B(3,2),VARXY(3)
40 DO 10 I=1,3
50 N(I)=0
60 DO 10 J=1,2
70 SX(I,J)=0.
80 SY(I,J)=0.
90 10 SXY(I,J)=0.
100 IS=1
110 20 WRITE(9,30)IS
120 30 FORMAT(/23HNAME OF INPUT DATA FILE,I2)
130 READ(9,40)NAM
140 40 FORMAT(6A2)
150 CALL DEFINE(IS,NAM)
160 WRITE(9,50)
170 50 FORMAT(//11HINPUT DATA:/3X,11HINDEPENDENT,3X,9HDEPENDENT)
180 READ(IS,60)LNO,N(IS)
190 60 FORMAT(2I6)
200 NS=N(IS)
210 DO 70 I=1,NS
220 READ(IS,80)LNO,X(IS,I),Y(IS,I)
230 80 FORMAT(I6,3D20.0)
240 EX=X(IS,I)
250 EY=Y(IS,I)
260 70 WRITE(9,90)EX,EY
270 READ(IS,80)LNO,SY(IS,1)
280 READ(IS,80)LNO,SX(IS,1)
290 READ(IS,80)LNO,SX(IS,2)
300 READ(IS,80)LNO,SXY(IS,1)
310 READ(IS,80)LNO,SY(IS,2)
320 READ(IS,80)LNO,B(IS,1)
330 READ(IS,80)LNO,B(IS,2)
340 READ(IS,80)LNO,SXY(IS,2)
350 90 FORMAT(2E14.6)
360 IS=IS+1
370 IF(IS-2)20,20,100
380 100 DO 140 I=1,IS
390 GOTO(110,110,130),I
400 110 DO 120 J=1,2
410 SX(IS,I)=SX(IS,I)+SX(J,I)
420 120 SY(IS,I)=SY(IS,I)+SY(J,I)
430 N(IS)=N(IS)+N(I)
440 SXY(IS,1)=SXY(IS,1)+SXY(I,1)
450 130 EN(I)=N(I)
460 XBAR(I)=SX(I,1)/EN(I)
470 YBAR(I)=SY(I,1)/EN(I)
480 VARX(I)=SX(I,2)-SX(I,1)**2/EN(I)
490 VARY(I)=SY(I,2)-SY(I,1)**2/EN(I)
500 SXY(I,2)=SXY(I,1)-SX(I,1)*SY(I,1)/EN(I)
```

```
B(IS,2)=SXY(I,2)/VARX(I)
140VARXY(I)=(VARY(I)-B(IS,2)**2*VARX(I))/(EN(I)-2.D0)
EFF=VARXY(1)/VARXY(2)
IDF1=N(1)-2
IDF2=N(2)-2
WRITE(9,150)IDF1,IDF2,EFF
150FORMAT(/I4,1H,,I4,'   DEGREES OF FREEDOM'/E10.4,'  F RATIO'//)
DO 180 I=1,2
READ (2,200)LNO,CL,F
IFRAT(I)=1
WRITE (9,160)CL,F
160FORMAT(F7.1,19H % CONFIDENCE LEVEL/
+,F7.3,24H VALUE OF F DISTRIBUTION)
IF(EFF.LE.F)GOTO180
IFRAT(I)=2
WRITE(9,170)
170 FORMAT(19HSIGNIFICANT, CANNOT )
180 WRITE(9,190)
190 FORMAT(44HACCEPT THE HYPOTHESIS THAT THE VARIANCES ARE
+6H EQUAL/)
IF((IFRAT(1).EQ.2).AND.(IFRAT(2).EQ.2))GOTO350
B1MB2=B(1,2)-B(2,2)
DF=N(1)+N(2)-4
NDF=DF
SYXP2=((EN(1)-2.D0)*VARXY(1)+(EN(2)-2.D0)*VARXY(2))/DF
VARBMB=SYXP2*(1.D0/VARX(1)+1.D0/VARX(2))
TEE=B1MB2/SQRT(VARBMB)
DO 290 I=1,2
READ(2,200)LNO,CL,T
200 FORMAT(I6,3G10.0)
ITRAT(1,I)=1
IF(I.EQ.2)GOTO220
WRITE(9,210)NDF,TEE
210 FORMAT(/I7,19H DEGREES OF FREEDOM/
+F7.3,22H VALUE OF T CALCULATED/)
220 IF(IFRAT(I).EQ.2)GOTO290
IF(ABS(TEE).GT.T)ITRAT(1,I)=2
WRITE(9,230)CL,T
230 FORMAT(/F7.1,19H % CONFIDENCE LEVEL
+/F7.3,33H ABSOLUTE VALUE OF T DISTRIBUTION)
IF(ITRAT(1,1).EQ.2)GOTO260
WRITE(9,250)
250 FORMAT(40HNON-SIGNIFICANT (THE LINES ARE PARALLEL)//)
GOTO290
260 WRITE(9,270)
270 FORMAT(/40HSIGNIFICANT (THE LINES ARE NOT PARALLEL)//)
290 CONTINUE
IF((ITRAT(1,1).EQ.2).AND.(ITRAT(1,2).EQ.2))GOTO350
XVARPL=VARX(1)+VARX(2)
B(3,2)=(SXY(1,2)+SXY(2,2))/XVARPL
SXYTWO=VARY(1)+VARY(2)-B(3,2)*(SXY(1,2)+SXY(2,2))
```

```
DF=N(1)+N(2)-3
NDF=DF
SYXP2=SXYTWO/DF
XBARMI=XBAR(1)-XBAR(2)
TEE=(YBAR(1)-YBAR(2)-B(3,2)*XBARMI)/SQRT(SYXP2*(1.DO/EN(1) +
+1.DO/EN(2) + XBARMI**2/XVARPL))
DO 340 I=1,2
READ(2,200)LNO,CL,T
ITRAT(2,I)=1
IF(I.EQ.2)GOTO295
WRITE(9,210)NDF,TEE
295 IF((IFRAT(I).EQ.2).OR.(ITRAT(1,I).EQ.2))GOTO340
IF(ABS(TEE).GT.T)ITRAT(2,I)=2
WRITE(9,230)CL,T
IF(ITRAT(2,I).EQ.2)GOTO320
WRITE(9,310)
310FORMAT(/47HNON-SIGNIFICANT (THE LINES CAN BE REGARDED AS A
+24H SINGLE COINCIDENT LINE))
GOTO340
320 WRITE(9,330)
330FORMAT(42HSIGNIFICANT (THE LINES ARE NOT COINCIDENT))
340 CONTINUE
350 STOP
END
```

APPENDIX B

DSC TEST DATA

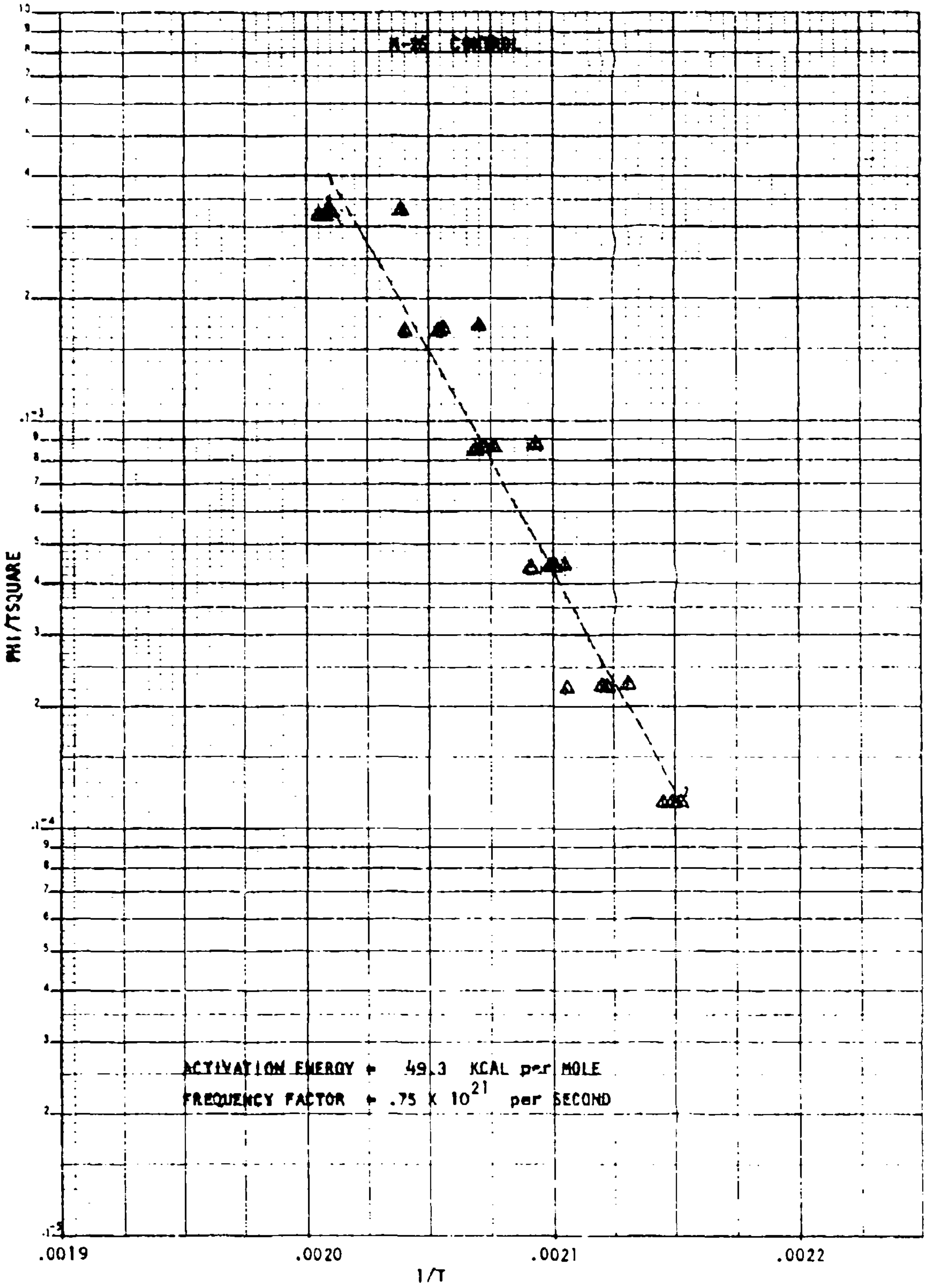
M-26 CONTROL

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	497.57	0.2010E-02	0.3231E-03
80.00	498.67	0.2005E-02	0.3217E-03
80.00	497.67	0.2009E-02	0.3230E-03
80.00	497.48	0.2010E-02	0.3233E-03
80.00	490.72	0.2038E-02	0.3322E-03
40.00	486.35	0.2056E-02	0.1691E-03
40.00	486.55	0.2055E-02	0.1690E-03
40.00	490.21	0.2040E-02	0.1665E-03
40.00	483.00	0.2070E-02	0.1715E-03
20.00	483.27	0.2069E-02	0.8563E-04
20.00	481.70	0.2076E-02	0.8619E-04
20.00	482.58	0.2072E-02	0.8588E-04
20.00	477.86	0.2093E-02	0.8758E-04
10.00	475.07	0.2105E-02	0.4431E-04
10.00	476.25	0.2100E-02	0.4409E-04
10.00	478.11	0.2092E-02	0.4375E-04
10.00	476.34	0.2099E-02	0.4407E-04
5.00	471.39	0.2121E-02	0.2250E-04
5.00	471.29	0.2122E-02	0.2251E-04
5.00	474.91	0.2106E-02	0.2217E-04
5.00	469.24	0.2131E-02	0.2271E-04
2.50	466.42	0.2144E-02	0.1149E-04
2.50	465.25	0.2149E-02	0.1155E-04
2.50	465.44	0.2149E-02	0.1154E-04
2.50	464.67	0.2152E-02	0.1158E-04

E (KCAL/MOLE) 0.492896E 02
A (SEC-1) 0.748259E 21

DEGREES KELVIN	K (SEC -1)	PERCENT, UNREACTED, (TIME IN YEARS) 1.0	2.0	5.0	10.0	20.0
298.0	0.53E-15	100.00	100.00	100.00	100.00	100.00
323.0	0.33E-12	100.00	100.00	99.99	99.99	99.98
348.0	0.83E-10	99.74	99.48	98.71	97.43	94.93
373.0	0.98E-08	73.39	53.86	21.29	4.53	0.21


CONTROL
PHI/TSQUARE
1/T
.0019
.0020
.0021
.0022
ACTIVATION ENERGY = 49.3 KCAL per MOLE
FREQUENCY FACTOR = .75 X 10^21 per SECOND

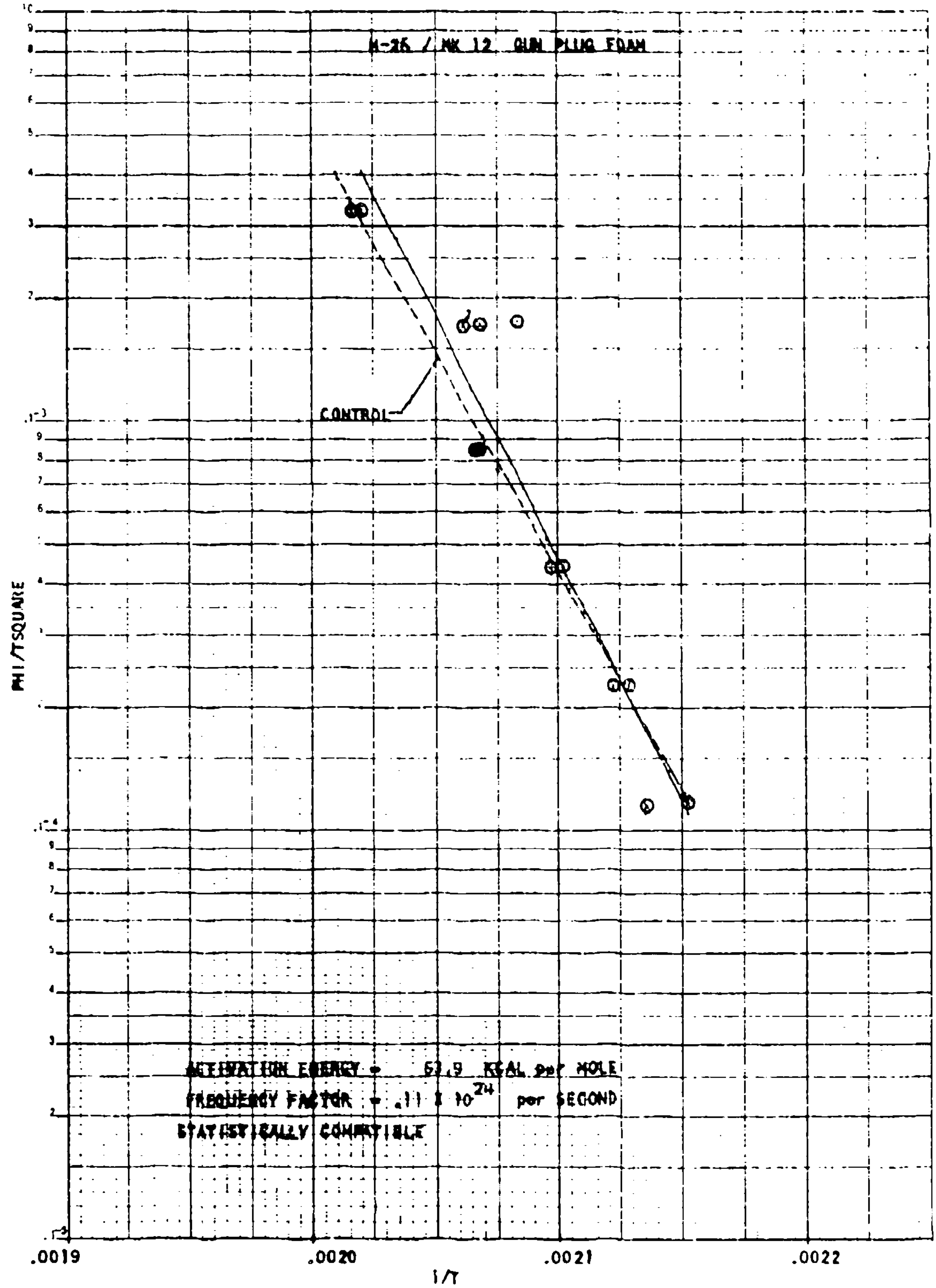
M-26 / MK 12 GUN PLUG FOAM

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	494.99	0.2020E-02	0.3265E-03
80.00	495.68	0.2017E-02	0.3256E-03
40.00	484.87	0.2062E-02	0.1701E-03
40.00	483.49	0.2068E-02	0.1711E-03
40.00	480.14	0.2083E-02	0.1735E-03
40.00	485.07	0.2062E-02	0.1700E-03
20.00	483.86	0.2067E-02	0.8543E-04
20.00	483.67	0.2068E-02	0.8549E-04
10.00	476.93	0.2097E-02	0.4396E-04
10.00	475.66	0.2102E-02	0.4420E-04
5.00	471.39	0.2121E-02	0.2250E-04
5.00	469.63	0.2129E-02	0.2267E-04
2.50	468.17	0.2136E-02	0.1141E-04
2.50	464.47	0.2153E-02	0.1159E-04

E (KCAL/MOLE) 0.538624E 02
A (SEC-1) 0.112227E 24

DEGREES KELVIN	K (SEC -1)	PERCENT, UNREACTED, (TIME IN YEARS) 1.0	2.0	5.0	10.0	20.0
298.0	0.00E 00	100.00	100.00	100.00	100.00	100.00
323.0	0.40E-13	100.00	100.00	100.00	100.00	100.00
343.0	0.17E-10	99.95	99.90	99.74	99.48	98.96
373.0	0.31E-08	90.75	82.36	61.55	37.89	14.36


M-26 / MK 12 GUN PLUG FOAM
CONTROL
PHI/TSQUARE
1/T
.0019
.0020
.0021
.0022
ACTIVATION ENERGY = 53.9 KCAL per MOLE
FREQUENCY FACTOR = .11 X 10^24 per SECOND
STATISTICALLY COMPATIBLE

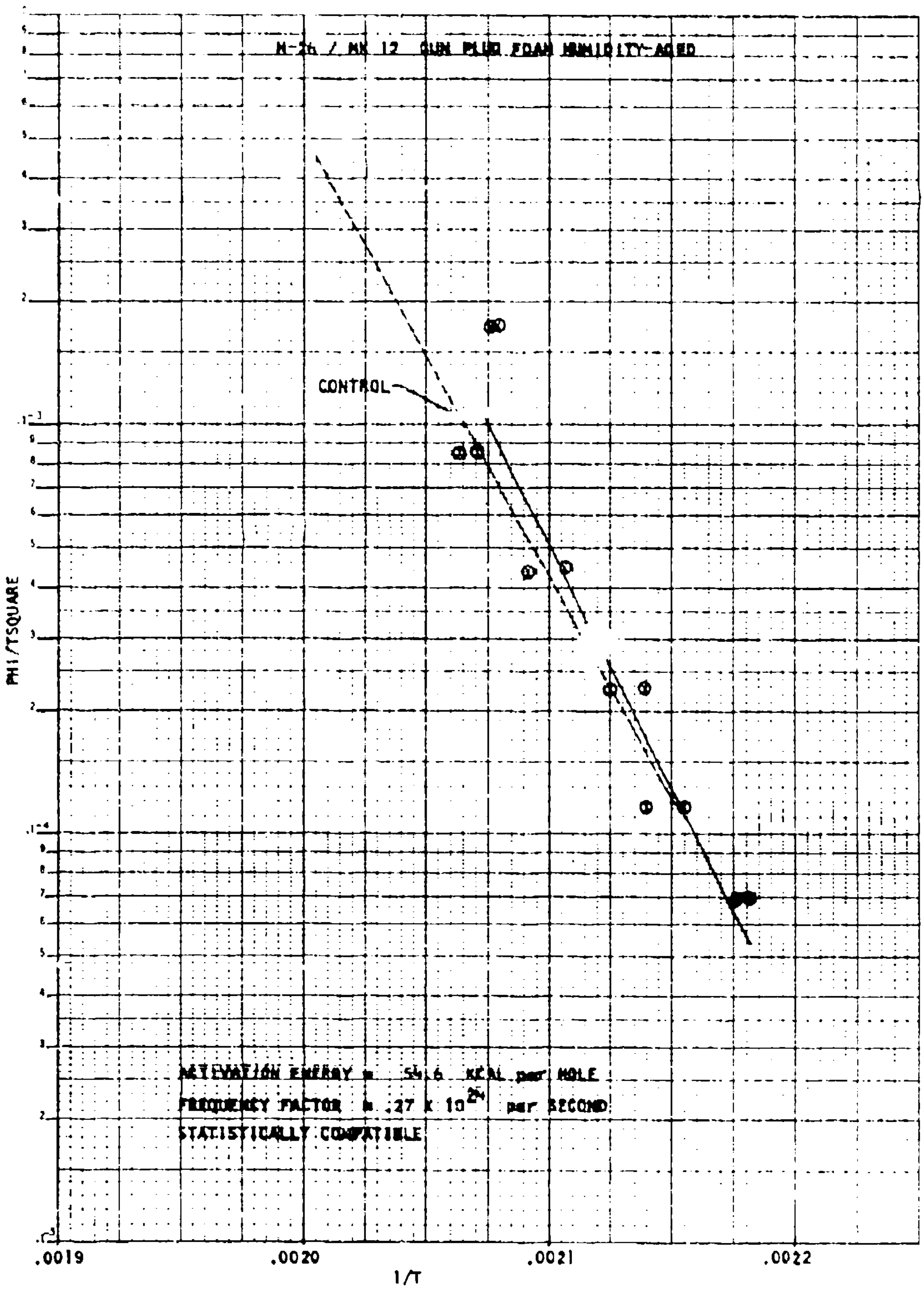
M-26 / MK 12 GUN PLUG FOAM,
HIMIDITY-AGED

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
40.00	481.08	0.2079E-02	0.1728E-03
40.00	481.57	0.2077E-02	0.1725E-03
20.00	484.44	0.2064E-02	0.8522E-04
20.00	482.95	0.2071E-02	0.8575E-04
10.00	477.93	0.2092E-02	0.4378E-04
10.00	474.50	0.2107E-02	0.4441E-04
5.00	467.67	0.2138E-02	0.2286E-04
5.00	470.60	0.2125E-02	0.2258E-04
2.50	467.34	0.2140E-02	0.1145E-04
2.50	463.93	0.2155E-02	0.1162E-04
1.25	459.32	0.2177E-02	0.5925E-05
1.25	458.35	0.2182E-02	0.5950E-05

E (KCAL/MOLE) 0.545899E 02
A (SEC-1) 0.265494E 24

DEGREES	K	PERCENT, UNREACTED, (TIME IN YEARS)				
KELVIN	(SEC -1)	1.0	2.0	5.0	10.0	20.0
298.0	0.00E 00	100.00	100.00	100.00	100.00	100.00
323.0	0.30E-13	100.00	100.00	100.00	100.00	100.00
348.0	0.14E-10	99.96	99.91	99.78	99.57	99.14
373.0	0.27E-08	91.76	84.19	65.04	42.30	17.90


M-26 / MK 12 GUN PLUG FOAM HUMIDITY-AGED
CONTROL
ACTIVATION ENERGY = 54.6 KCAL per MOLE
FREQUENCY FACTOR = .27 x 10^24 per SECOND
STATISTICALLY COMPATIBLE
PHI/TSQUARE
.0019
.0020
.0021
.0022
1/T

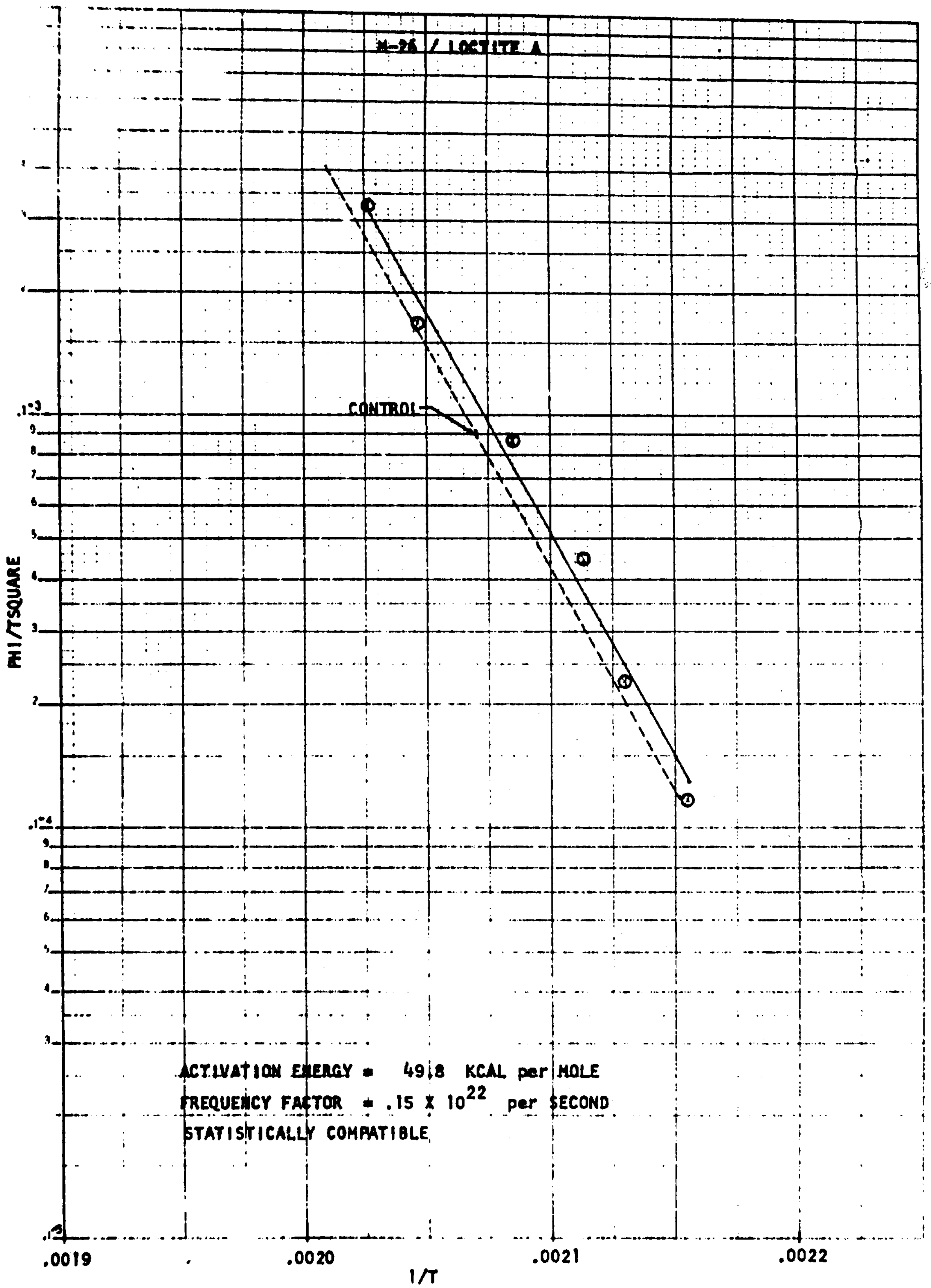
M-26 / LOCTITE A

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	493.50	0.2026E-02	0.3285E-03
40.00	488.53	0.2047E-02	0.1676E-03
20.00	479.73	0.2085E-02	0.8690E-04
10.00	473.12	0.2114E-02	0.4467E-04
5.00	469.53	0.2130E-02	0.2268E-04
2.50	463.98	0.2155E-02	0.1161E-04

E (KCAL/MOLE) 0.497688E 02
A (SEC-1) 0.150313E 22

DEGREES	K	PERCENT, UNREACTED, (TIME IN YEARS)				
KELVIN	(SEC -1)	1.0	2.0	5.0	10.0	20.0
298.0	0.47E-15	100.00	100.00	100.00	100.00	100.00
323.0	0.32E-12	100.00	100.00	100.00	99.99	99.98
348.0	0.83E-10	99.74	99.48	98.70	97.42	94.90
373.0	0.10E-07	72.21	52.15	19.64	3.86	0.15



M-26 / LOCTITE A
CONTROL
ACTIVATION ENERGY = 49.8 KCAL per MOLE
FREQUENCY FACTOR = .15 X 10^22 per SECOND
STATISTICALLY COMPATIBLE
PHI/TSQUARE
1/T
.0019
.0020
.0021
.0022

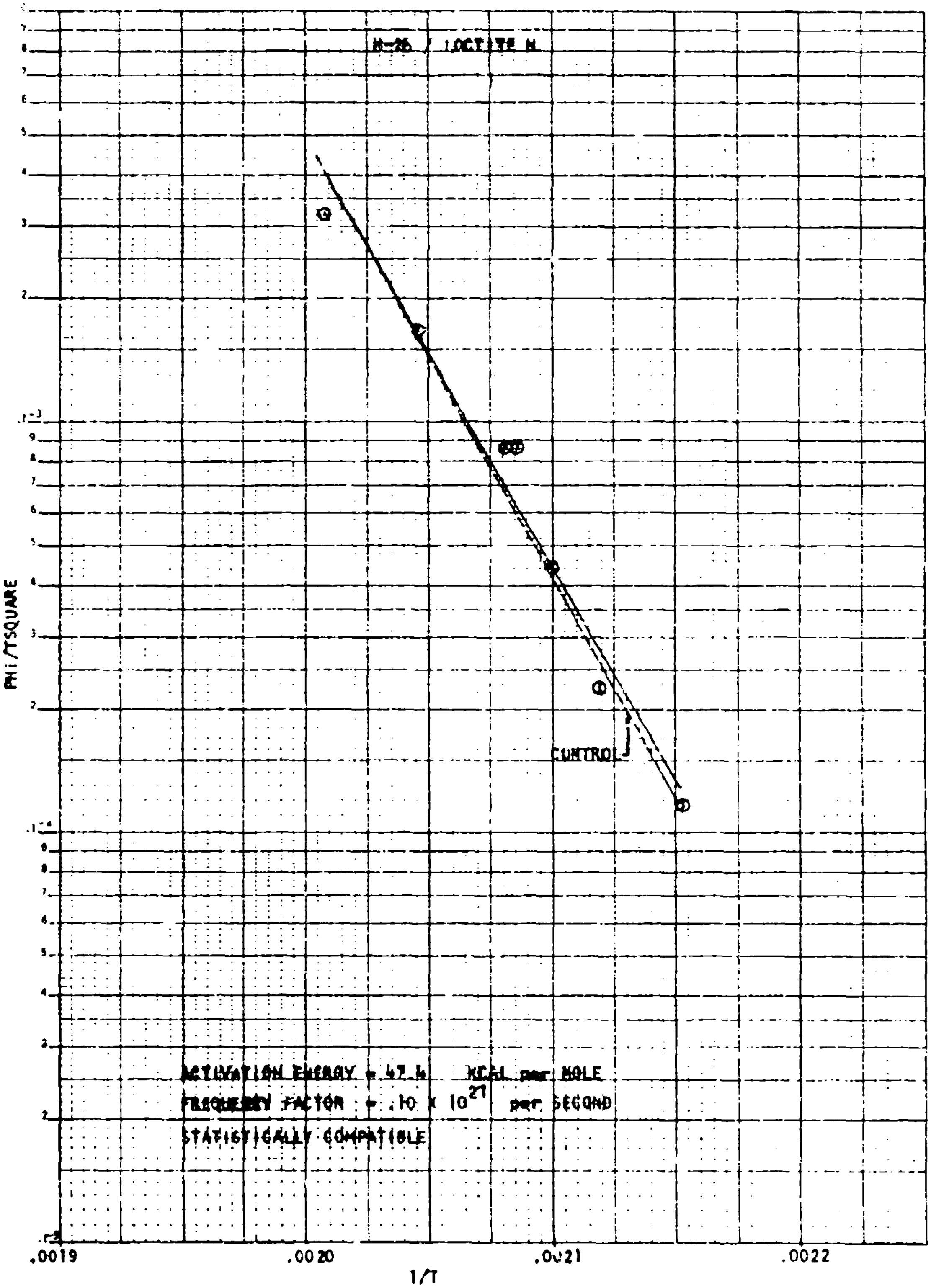
M-26 / LOCTITE N

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	497.97	0.2008E-02	0.3226E-03
40.00	483.73	0.2046E-02	0.1675E-03
20.00	479.34	0.2086E-02	0.8704E-04
20.00	480.42	0.2082E-02	0.8665E-04
10.00	476.15	0.2100E-02	0.4411E-04
5.00	471.98	0.2119E-02	0.2245E-04
2.50	464.57	0.2153E-02	0.1158E-04

E (KCAL/MOLE) 0.474187E 02
A (SEC-1) 0.103894E 21

DEGREES	K	PERCENT, UNREACTED, (TIME IN YEARS)				
KELVIN	(SEC -1)	1.0	2.0	5.0	10.0	20.0
298.0	0.17E-14	100.00	100.00	100.00	100.00	100.00
323.0	0.85E-12	100.00	99.99	99.99	99.97	99.95
348.0	0.17E-09	99.46	98.92	97.33	94.73	89.74
373.0	0.17E-07	58.50	34.22	6.85	0.47	0.00



N-75 / LOCTITE N
PHI/TSQUARE
1/T
.0019
.0020
.0021
.0022
CONTROL
ACTIVATION ENERGY = 47.4 KCAL per MOLE
FREQUENCY FACTOR = .10 X 10^27 per SECOND
STATISTICALLY COMPATIBLE

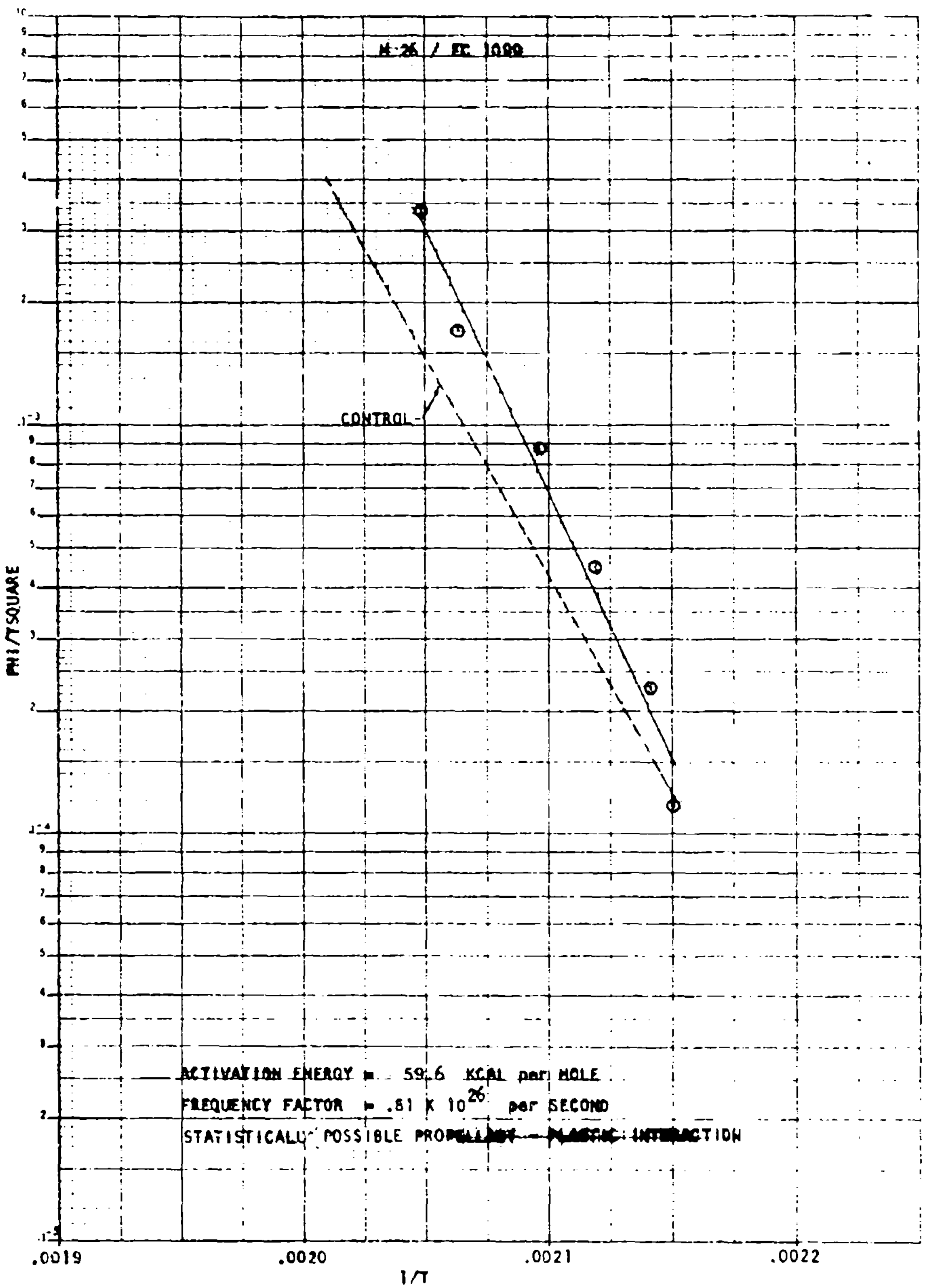
M-26 / EC 1099

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	488.04	0.2049E-02	0.3359E-03
40.00	484.77	0.2063E-02	0.1702E-03
20.00	477.08	0.2096E-02	0.8787E-04
10.00	471.85	0.2119E-02	0.4492E-04
5.00	467.00	0.2141E-02	0.2293E-04
2.50	464.96	0.2151E-02	0.1156E-04

E (KCAL/MOLE) 0.596298E 02
A (SEC-1) 0.806879E 26

DEGREES	K	PERCENT, UNREACTED, (TIME IN YEARS)				
KELVIN	(SEC -1)	1.0	2.0	5.0	10.0	20.0
298.0	0.00E 00	100.00	100.00	100.00	100.00	100.00
323.0	0.00E 00	100.00	100.00	100.00	100.00	100.00
348.0	0.29E-11	99.99	99.98	99.96	99.91	99.82
373.0	0.92E-09	97.13	94.34	86.45	74.74	55.86


M-26 / FC 1000
CONTROL
PHI/TSQUARE
ACTIVATION ENERGY = 59.6 KCAL per MOLE
FREQUENCY FACTOR = .81 X 10^26 per SECOND
STATISTICALLY POSSIBLE PROPELLANT - PLASTIC INTERACTION
.0019
.0020
.0021
.0022
1/T

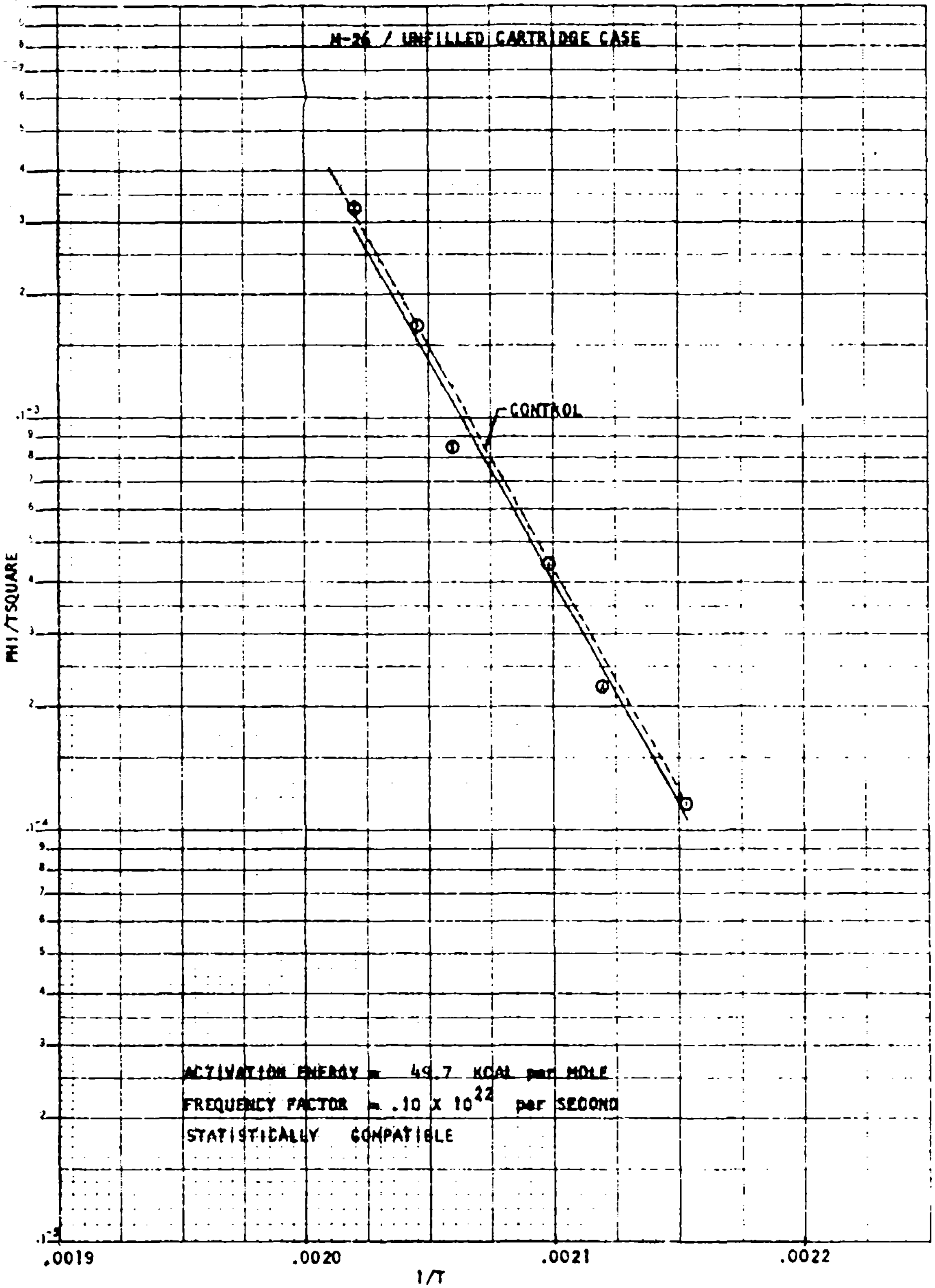
M-26 / UNFILLED CARTRIDGE CASE

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	494.99	0.2020E-02	0.3265E-03
40.00	488.73	0.2046E-02	0.1675E-03
20.00	485.64	0.2059E-02	0.8480E-04
10.00	476.54	0.2098E-02	0.4404E-04
5.00	471.88	0.2119E-02	0.2245E-04
2.50	464.47	0.2153E-02	0.1159E-04

E (KCAL/MOLE) 0.496687E 02
A (SEC-1) 0.103975E 22

DEGREES	K	PERCENT, UNREACTED, (TIME IN YEARS)				
KELVIN	(SEC -1)	1.0	2.0	5.0	10.0	20.0
298.0	0.39E-15	100.00	100.00	100.00	100.00	100.00
323.0	0.26E-12	100.00	100.00	100.00	99.99	99.98
348.0	0.66E-10	99.79	99.58	98.96	97.93	95.90
373.0	0.82E-08	77.28	59.72	27.56	7.60	0.58


M-26 / UNFILLED CARTRIDGE CASE
CONTROL
ACTIVATION ENERGY = 49.7 KCAL per MOLE
FREQUENCY FACTOR = .10 X 10^22 per SECOND
STATISTICALLY COMPATIBLE
PHI/TSQUARE
.0019
.0020
.0021
.0022
1/T

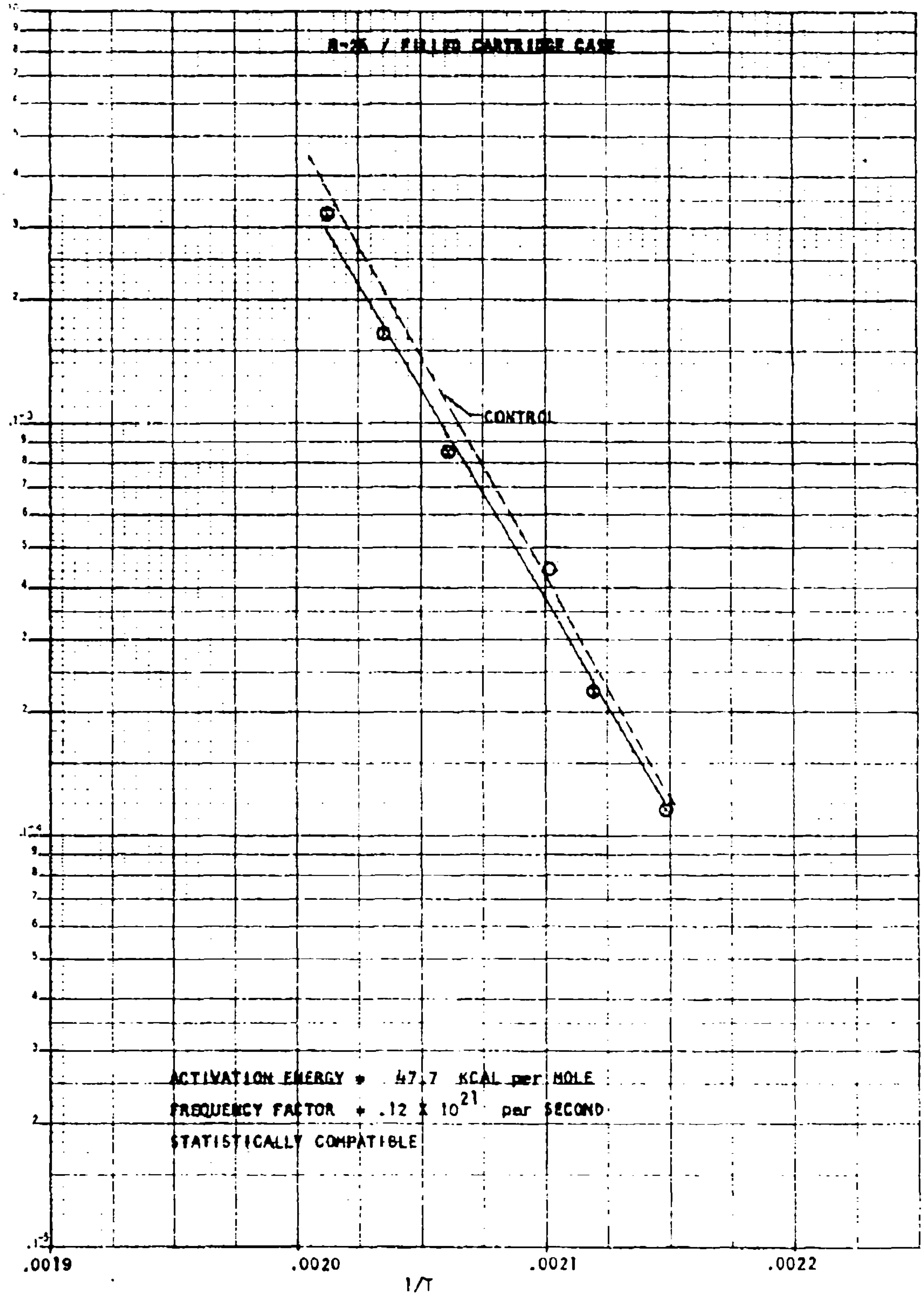
M-26 / FILLED CARTRIDGE CASE

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	496.98	0.2012E-02	0.3239E-03
40.00	491.50	0.2035E-02	0.1656E-03
20.00	485.15	0.2061E-02	0.8497E-04
20.00	484.95	0.2062E-02	0.8504E-04
5.00	471.78	0.2120E-02	0.2246E-04
2.50	465.44	0.2149E-02	0.1154E-04

E (KCAL/MOLE) 0.477363E 02
A (SEC-1) 0.116241E 21

DEGREES KELVIN	K (SEC -1)	PERCENT, UNREACTED, (TIME IN YEARS) 1.0	2.0	5.0	10.0	20.0
298.0	0.11E-14	100.00	100.00	100.00	100.00	100.00
323.0	0.58E-12	100.00	100.00	99.99	99.98	99.96
348.0	0.12E-09	99.62	99.24	98.11	96.25	92.64
373.0	0.12E-07	67.65	45.76	14.17	2.01	0.04



FILLED CARTRIDGE CASE
CONTROL
ACTIVATION ENERGY = 47.7 KCAL per MOLE
FREQUENCY FACTOR = .12 X 10^21 per SECOND
STATISTICALLY COMPATIBLE
.0019
.0020
.0021
.0022
1/T

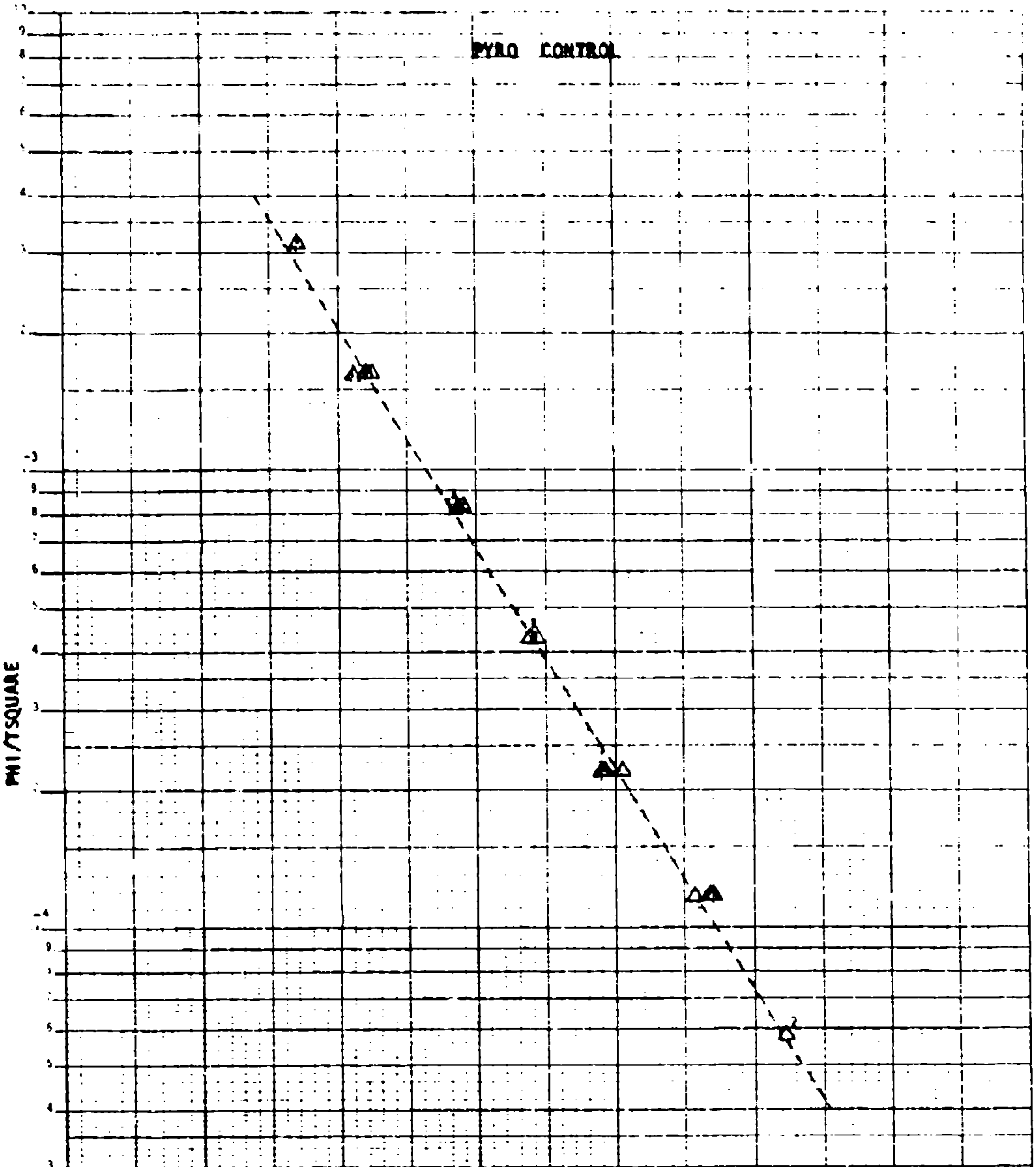
PYRO CONTROL

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	503.47	0.1986E-02	0.3156E-03
40.00	496.90	0.2012E-02	0.1620E-03
40.00	498.39	0.2006E-02	0.1610E-03
40.00	497.45	0.2010E-02	0.1616E-03
20.00	488.93	0.2045E-02	0.8366E-04
20.00	489.43	0.2043E-02	0.8349E-04
20.00	489.49	0.2043E-02	0.8347E-04
10.00	482.86	0.2071E-02	0.4289E-04
10.00	482.86	0.2071E-02	0.4289E-04
10.00	483.32	0.2069E-02	0.4281E-04
5.00	476.98	0.2097E-02	0.2198E-04
5.00	477.48	0.2094E-02	0.2193E-04
5.00	475.80	0.2102E-02	0.2209E-04
2.50	468.81	0.2133E-02	0.1137E-04
2.50	468.32	0.2135E-02	0.1140E-04
2.50	469.93	0.2128E-02	0.1132E-04
1.25	462.71	0.2161E-02	0.5838E-05
1.25	462.71	0.2161E-02	0.5838E-05

E (KCAL/MOLE) 0.443645E 02
A (SEC-1) 0.193012E 19

DEGREES KELVIN	K (SEC -1)	PERCENT, UNREACTED, (TIME IN YEARS) 1.0	2.0	5.0	10.0	20.0
298.0	0.56E-14	100.00	100.00	100.00	100.00	100.00
323.0	0.18E-11	99.99	99.99	99.97	99.94	99.88
348.0	0.26E-09	99.17	98.35	95.92	92.01	84.66
373.0	0.19E-07	54.13	29.30	4.65	0.22	0.00



PYRO CONTROL
ACTIVATION ENERGY = 44.4 KCAL per MOLE
FREQUENCY FACTOR = .19 X 10^19 per SECOND
PHI/TSQUARE
1/T
.0019
.0020
.0021
.0022

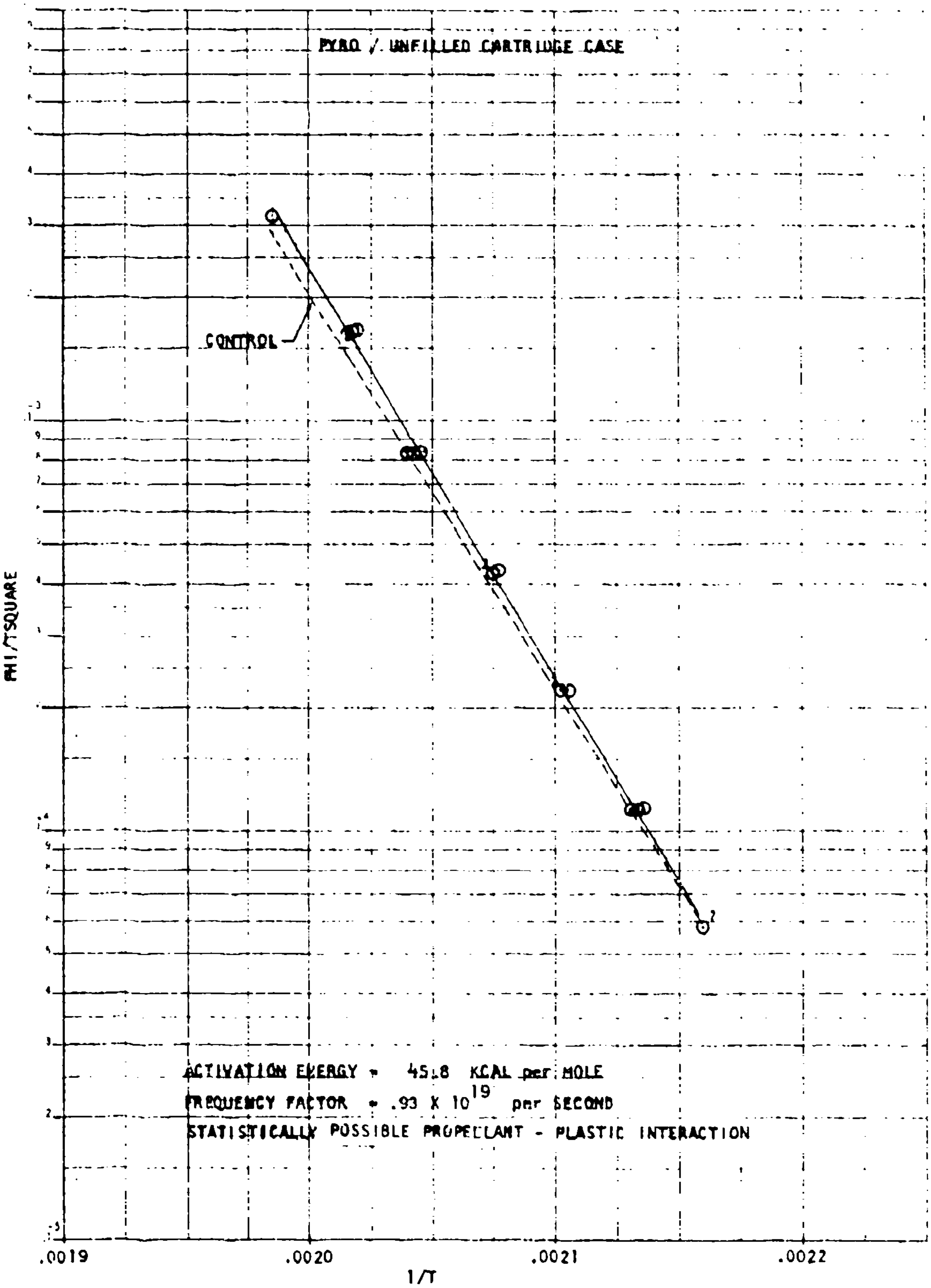
PYRO / UNFILLED CARTRIDGE CASE

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	503.97	0.1984E-02	0.3150E-03
40.00	495.91	0.2016E-02	0.1627E-03
40.00	494.91	0.2021E-02	0.1633E-03
40.00	495.47	0.2018E-02	0.1629E-03
20.00	490.43	0.2039E-02	0.8315E-04
20.00	488.43	0.2047E-02	0.8383E-04
20.00	489.00	0.2045E-02	0.8364E-04
10.00	481.87	0.2075E-02	0.4307E-04
10.00	481.87	0.2075E-02	0.4307E-04
10.00	481.55	0.2077E-02	0.4312E-04
5.00	475.51	0.2103E-02	0.2211E-04
5.00	475.51	0.2103E-02	0.2211E-04
5.00	475.11	0.2105E-02	0.2215E-04
2.50	468.81	0.2133E-02	0.1137E-04
2.50	468.32	0.2135E-02	0.1140E-04
2.50	469.54	0.2130E-02	0.1134E-04
1.25	463.20	0.2159E-02	0.5826E-05
1.25	463.20	0.2159E-02	0.5826E-05

E (KCAL/MOLE) 0.457713E 02
A (SEC-1) 0.932722E 19

DEGREES KELVIN	K (SEC -1)	PERCENT, UNREACTED, (TIME IN YEARS) 1.0	2.0	5.0	10.0	20.0
298.0	0.25E-14	100.00	100.00	100.00	100.00	100.00
323.0	0.99E-12	100.00	99.99	99.98	99.97	99.94
348.0	0.17E-09	99.48	98.95	97.40	94.88	90.01
373.0	0.14E-07	64.12	41.11	10.84	1.17	0.01



PYRO / UNFILLED CARTRIDGE CASE
CONTROL
PHI/TSQUARE
ACTIVATION ENERGY = 45.8 KCAL per MOLE
FREQUENCY FACTOR = .93 X 10^19 per SECOND
STATISTICALLY POSSIBLE PROPELLANT - PLASTIC INTERACTION
.0019
.0020
.0021
.0022
1/T

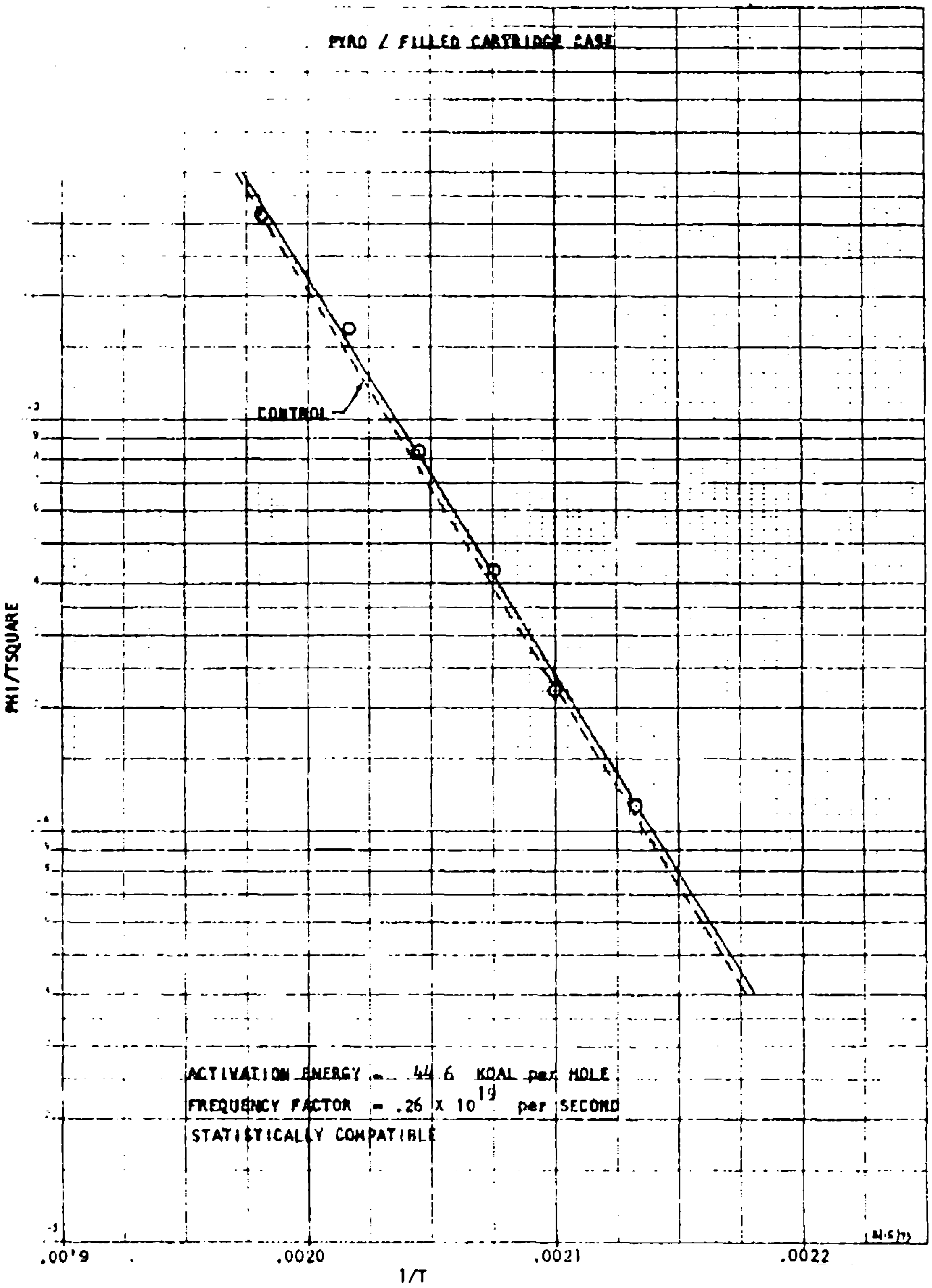
PYRO / FILLED CARTRIDGE CASE

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	504.67	0.1981E-02	0.3141E-03
40.00	495.67	0.2017E-02	0.1628E-03
20.00	489.00	0.2045E-02	0.8364E-04
10.00	482.04	0.2075E-02	0.4304E-04
5.00	476.19	0.2100E-02	0.2205E-04
2.50	468.85	0.2133E-02	0.1137E-04

E (KCAL/MOLE) 0.445877E 02
A (SEC-1) 0.253103E 19

DEGREES	K	PERCENT, UNREACTED, (TIME IN YEARS)				
KELVIN	(SEC -1)	1.0	2.0	5.0	10.0	20.0
298.0	0.51E-14	100.00	100.00	100.00	100.00	100.00
323.0	0.17E-11	99.99	99.99	99.97	99.95	99.89
348.0	0.26E-09	99.20	98.40	96.05	92.25	85.11
373.0	0.19E-07	54.48	29.68	4.80	0.23	0.00


PYRO / FILLED CARTRIDGE CASE
CONTROL
PHI/TSQUARE
ACTIVATION ENERGY = 44.6 KCAL per MOLE
FREQUENCY FACTOR = .26 X 10^19 per SECOND
STATISTICALLY COMPATIBLE
.0019
.0020
.0021
.0022
1/T

PYRO / ULTRABOND 76-125

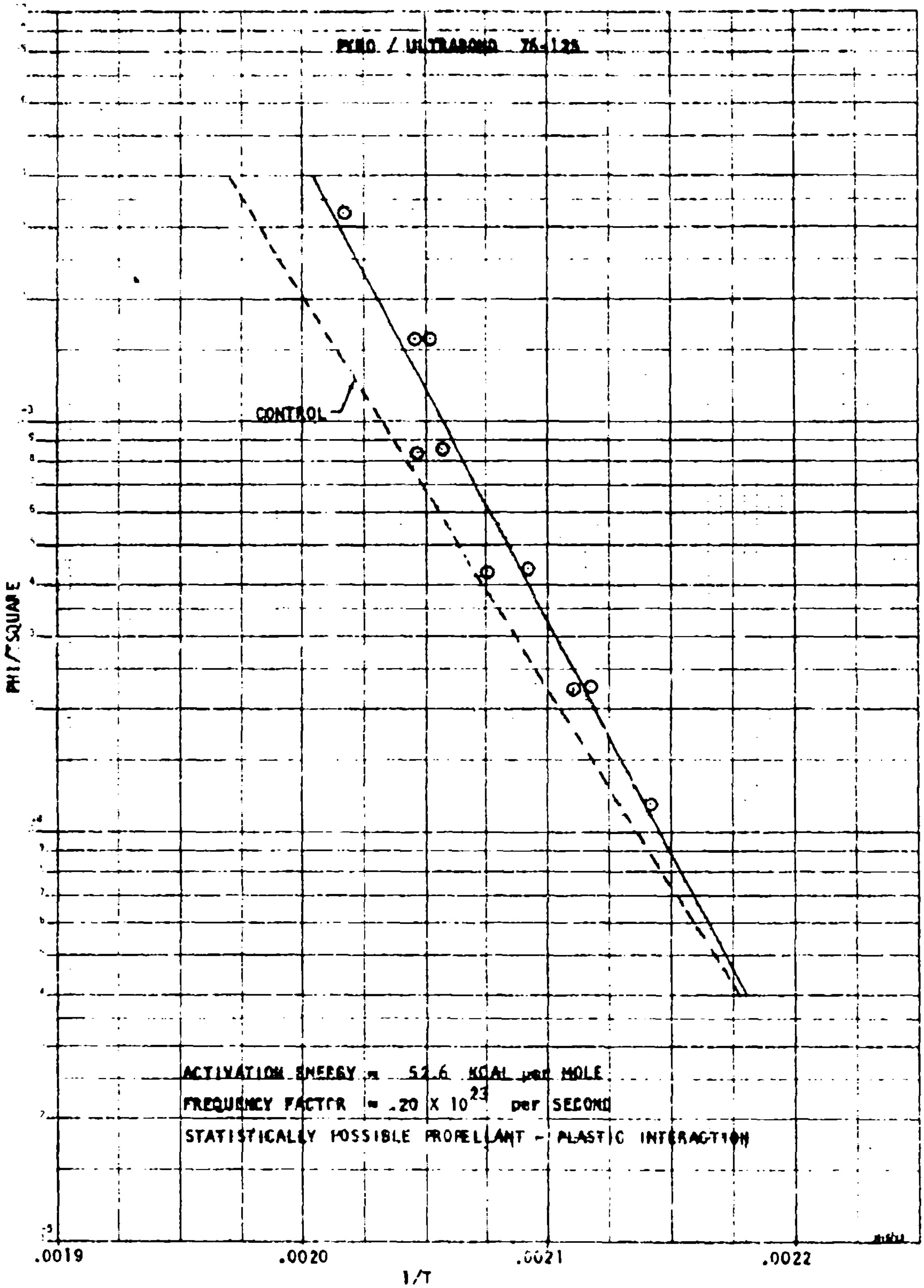
INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	495.78	0.2017E-02	0.3255E-03
40.00	488.73	0.2046E-02	0.1675E-03
40.00	487.24	0.2052E-02	0.1685E-03
20.00	488.50	0.2047E-02	0.8381E-04
20.00	486.03	0.2057E-02	0.8466E-04
10.00	477.91	0.2092E-02	0.4378E-04
10.00	481.64	0.2076E-02	0.4311E-04
5.00	472.37	0.2117E-02	0.2241E-04
5.00	474.03	0.2110E-02	0.2225E-04
2.50	466.81	0.2142E-02	0.1147E-04

E (KCAL/MOLE) 0.526131E 02

A (SEC-1) 0.199368E 23

DEGREES KELVIN	K (SEC -1)	PERCENT, UNREACTED, (TIME IN YEARS) 1.0	2.0	5.0	10.0	20.0
298.0	0.51E-16	100.00	100.00	100.00	100.00	100.00
323.0	0.50E-13	100.00	100.00	100.00	100.00	100.00
348.0	0.18E-10	99.94	99.89	99.72	99.43	98.87
373.0	0.29E-08	91.12	83.02	62.80	39.4	15.56


PYRO / ULTRABOND 76-125
CONTROL
PHI/"SQUARE
ACTIVATION ENERGY = 52.6 KCAL per MOLE
FREQUENCY FACTOR = .20 X 10^23 per SECOND
STATISTICALLY POSSIBLE PROPELLANT - PLASTIC INTERACTION
.0019
.0020
.0021
.0022
1/T

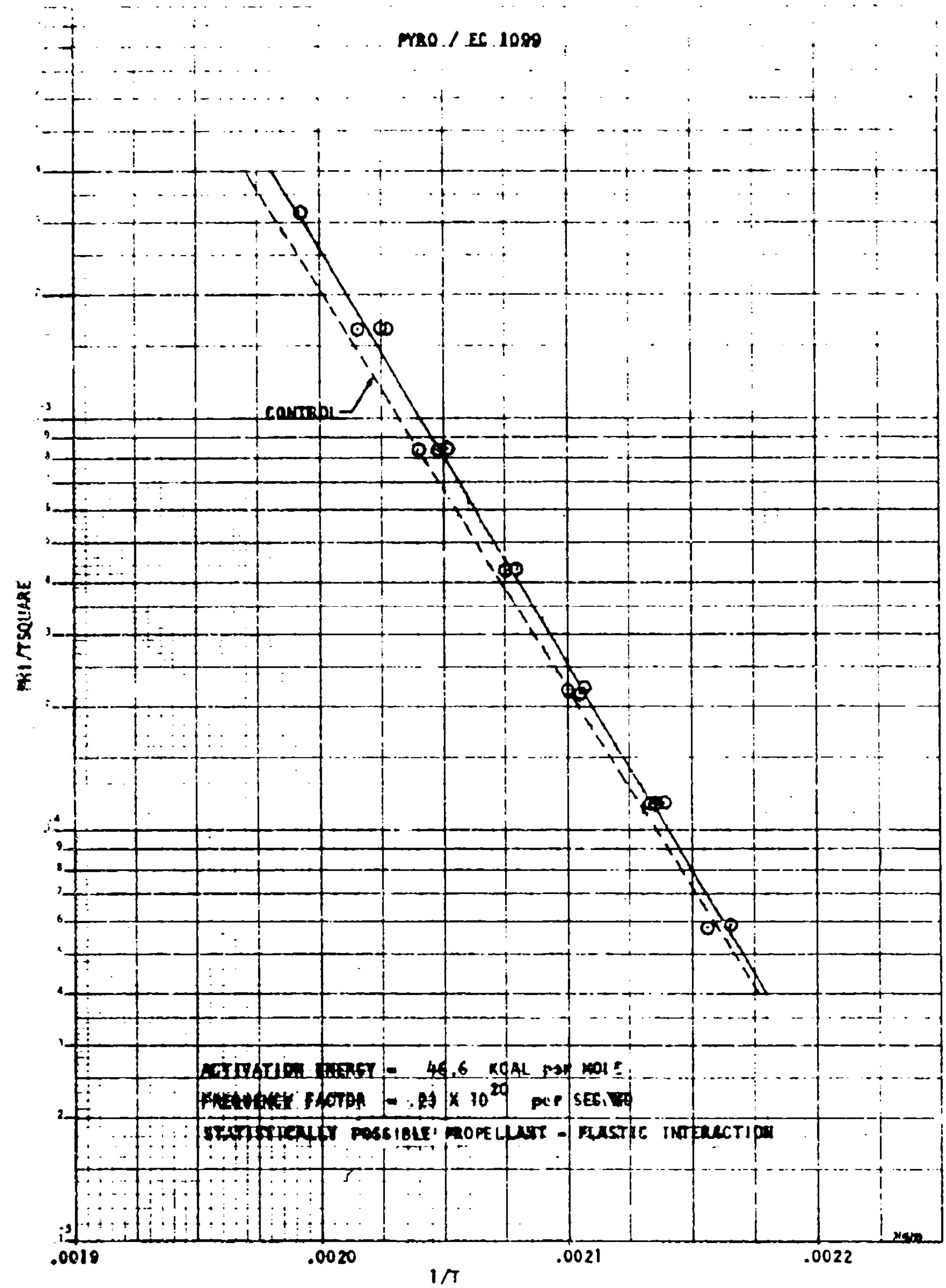
PYRO / EC 1099

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	501.97	0.1992E-02	0.3175E-03
40.00	495.91	0.2016E-02	0.1627E-03
40.00	493.43	0.2027E-02	0.1643E-03
40.00	493.98	0.2024E-02	0.1639E-03
20.00	487.43	0.2052E-02	0.8418E-04
20.00	490.43	0.2039E-02	0.8315E-04
20.00	488.30	0.2048E-02	0.8389E-04
10.00	480.89	0.2079E-02	0.4324E-04
10.00	481.87	0.2075E-02	0.4307E-04
10.00	481.84	0.2075E-02	0.4307E-04
5.00	476.49	0.2099E-02	0.2202E-04
5.00	475.21	0.2104E-02	0.2214E-04
5.00	474.53	0.2107E-02	0.2220E-04
2.50	467.83	0.2138E-02	0.1142E-04
2.50	463.76	0.2133E-02	0.1138E-04
2.50	468.32	0.2135E-02	0.1140E-04
1.25	461.74	0.2166E-02	0.5863E-05
1.25	463.68	0.2157E-02	0.5814E-05

E (KCAL/MOLE) 0.465567E 02
A (SEC-1) 0.228539E 20

DEGREES KELVIN	K (SEC -1)	PERCENT, UNREACTED, (TIME IN YEARS) 1.0	2.0	5.0	10.0	20.0
298.0	0.16E-14	100.00	100.00	100.00	100.00	100.00
323.0	0.72E-12	100.00	100.00	99.99	99.98	99.95
348.0	0.13E-09	99.59	99.18	97.95	95.94	92.05
373.0	0.12E-07	68.56	47.01	15.15	2.30	0.05


PYRO / EC 1099
CONTROL
K1/TSQUARE
1/T
.0019
.0020
.0021
.0022
ACTIVATION ENERGY = 46.6 KCAL per MOLE
FREQUENCY FACTOR = .23 X 10 20 per SEC.
STATISTICALLY POSSIBLE PROPELLANT - PLASTIC INTERACTION

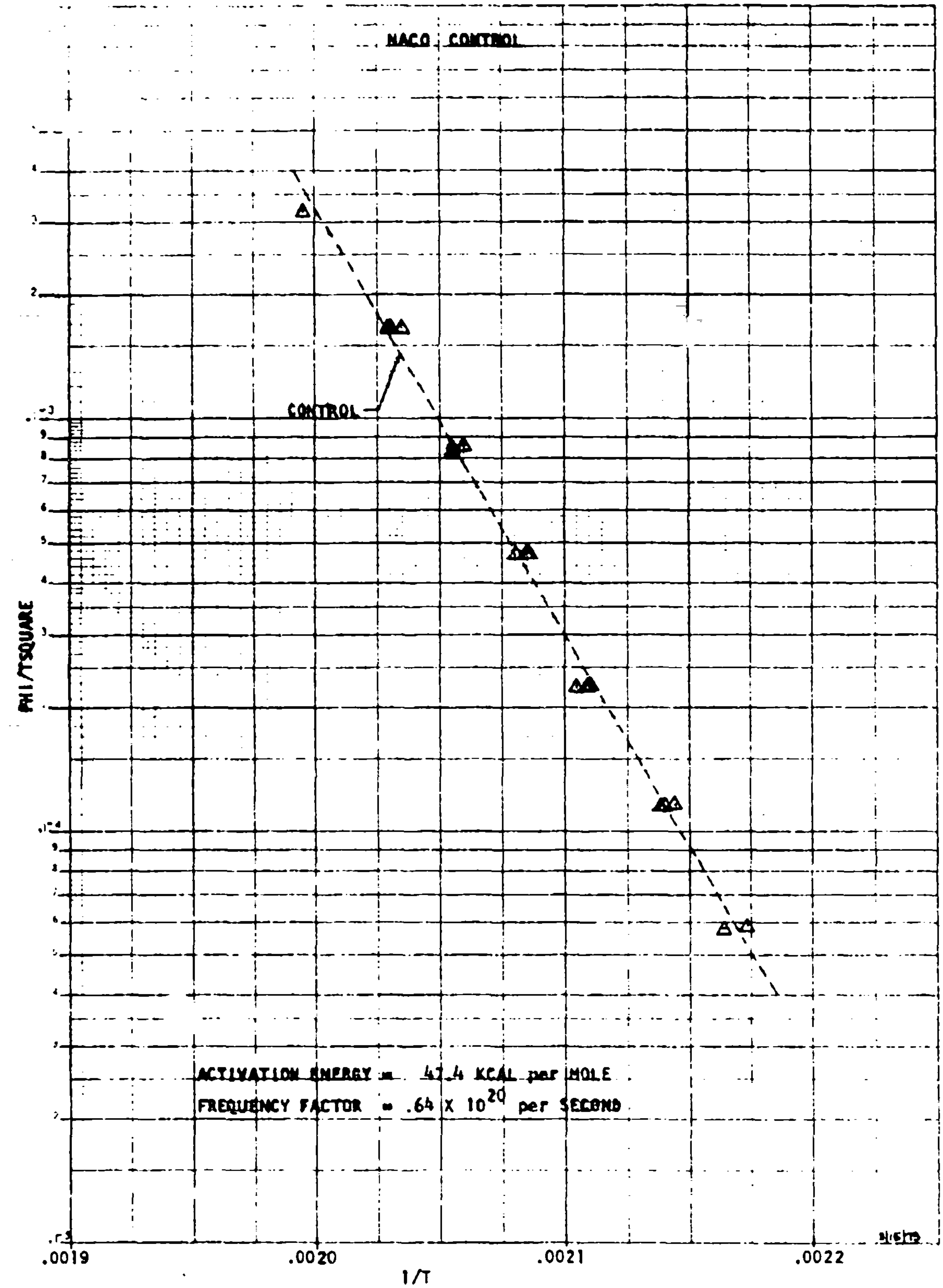
NACO CONTROL

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	501.27	0.1995E-02	0.3184E-03
40.00	492.44	0.2031E-02	0.1650E-03
40.00	492.93	0.2029E-02	0.1646E-03
40.00	491.70	0.2034E-02	0.1654E-03
20.00	486.44	0.2056E-02	0.8452E-04
20.00	485.44	0.2060E-02	0.8487E-04
20.00	486.72	0.2055E-02	0.8443E-04
10.00	479.90	0.2084E-02	0.4342E-04
10.00	479.41	0.2086E-02	0.4351E-04
10.00	480.86	0.2080E-02	0.4325E-04
5.00	474.04	0.2110E-02	0.2225E-04
5.00	475.02	0.2105E-02	0.2216E-04
5.00	473.64	0.2111E-02	0.2229E-04
2.50	466.37	0.2144E-02	0.1149E-04
2.50	467.64	0.2138E-02	0.1143E-04
2.50	467.39	0.2140E-02	0.1144E-04
1.25	460.29	0.2173E-02	0.5900E-05
1.25	462.23	0.2163E-02	0.5851E-05

E (KCAL/MOLE) 0.473649E 02
A (SEC-1) 0.643802E 20

DEGREES KELVIN	K (SEC -1)	PERCENT, UNREACTED, (TIME IN YEARS) 1.0	2.0	5.0	10.0	20.0
298.0	0.12E-14	100.00	100.00	100.00	100.00	100.00
323.0	0.57E-12	100.00	100.00	99.99	99.98	99.96
348.0	0.11E-09	99.64	99.28	98.20	96.44	93.01
373.0	0.11E-07	69.96	48.94	16.76	2.81	0.08


NACO CONTROL
CONTROL
PHI/TSQUARE
ACTIVATION ENERGY = 47.4 KCAL per MOLE
FREQUENCY FACTOR = .64 X 10^20 per SECOND
.0019
.0020
.0021
.0022
1/T

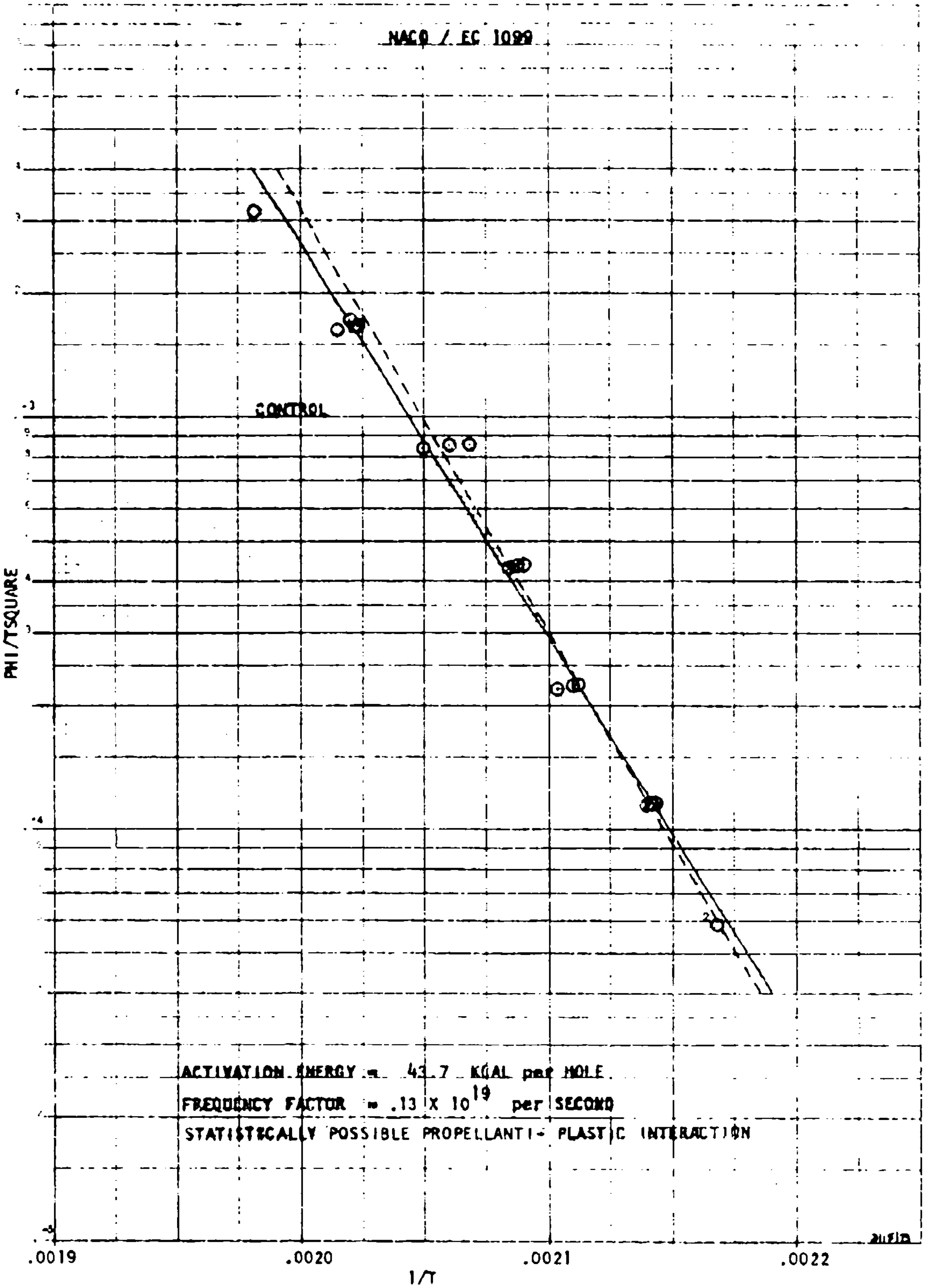
NACO / EC 1099

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	504.57	0.1982E-02	0.3142E-03
40.00	494.42	0.2023E-02	0.1636E-03
40.00	496.40	0.2015E-02	0.1623E-03
40.00	494.67	0.2022E-02	0.1635E-03
20.00	483.45	0.2068E-02	0.8557E-04
20.00	485.44	0.2060E-02	0.8487E-04
20.00	488.01	0.2049E-02	0.8398E-04
10.00	478.92	0.2088E-02	0.4360E-04
10.00	478.43	0.2090E-02	0.4369E-04
10.00	479.88	0.2084E-02	0.4342E-04
5.00	473.55	0.2112E-02	0.2230E-04
5.00	475.51	0.2103E-02	C.2211E-04
5.00	473.84	0.2110E-02	0.2227E-04
2.50	467.34	0.2140E-02	0.1145E-04
2.50	466.86	0.2142E-02	0.1147E-04
2.50	466.71	0.2143E-02	0.1148E-04
1.25	461.26	0.2168E-02	0.5875E-05
1.25	461.26	0.2168E-02	0.5875E-05

E (KCAL/MOLE) 0.437364E 02
A (SEC-1) 0.126858E 19

DEGREES	K	PERCENT, UNREACTED, (TIME IN YEARS)				
KELVIN	(SEC -1)	1.0	2.0	5.0	10.0	20.0
298.0	0.11E-13	100.00	100.00	100.00	100.00	100.00
323.0	0.32E-11	99.99	99.98	99.95	99.90	99.80
348.0	0.43E-09	98.65	97.32	93.44	87.31	76.23
373.0	0.30E-07	39.01	15.22	0.90	0.01	0.00



NACO / EC 1099
CONTROL
PHI/TSQUARE
ACTIVATION ENERGY = 43.7 KCAL per MOLE
FREQUENCY FACTOR = .13 X 10^19 per SECOND
STATISTICALLY POSSIBLE PROPELLANT - PLASTIC INTERACTION
.0019
.0020
.0021
.0022
1/T

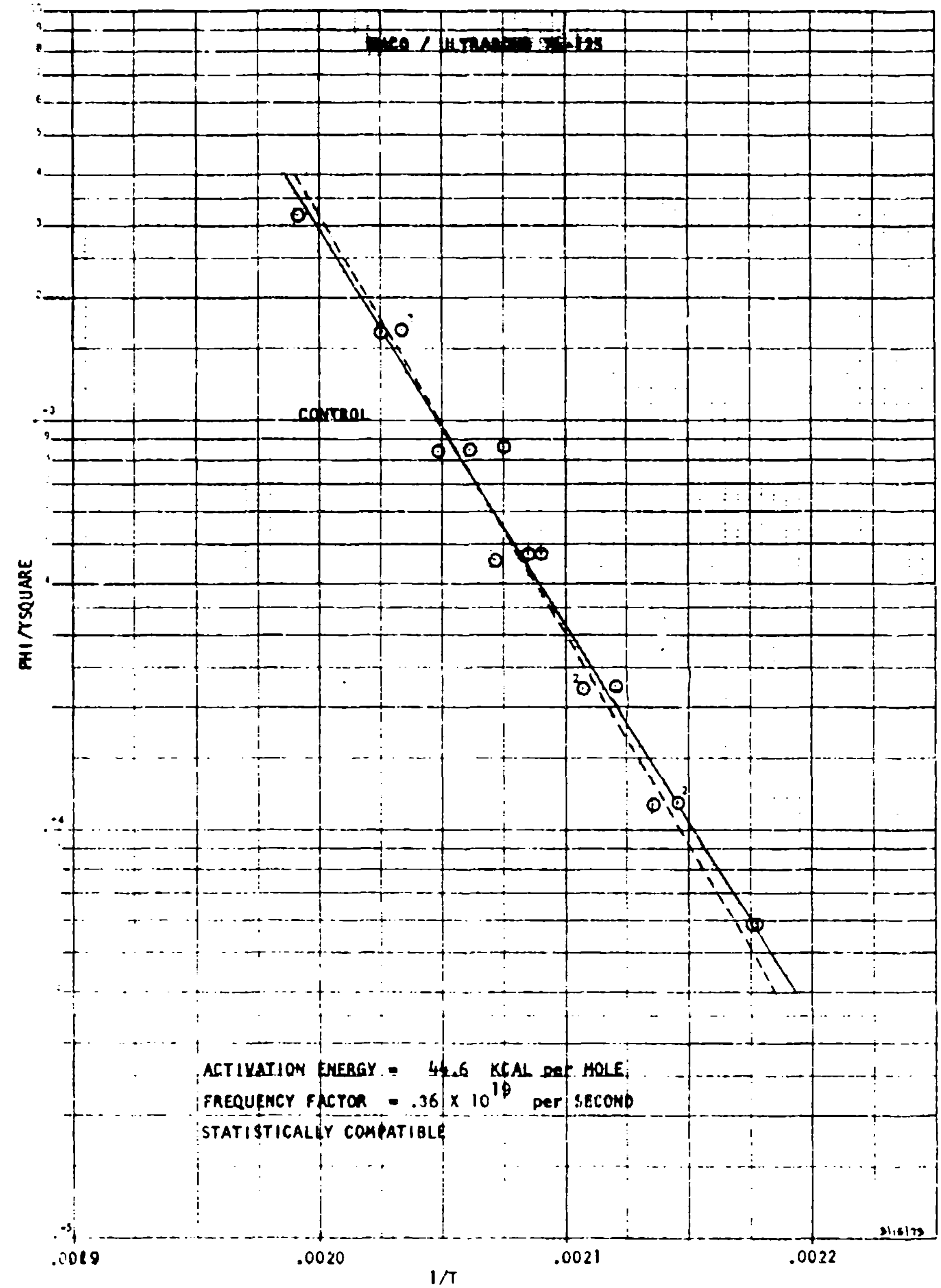
NACO / ULTRABOND 76-125

INPUT DATA

PHI	TEMP	1/T	PHI/TSQUARE
80.00	501.97	0.1992E-02	0.3175E-03
40.00	491.94	0.2033E-02	0.1653E-03
40.00	491.94	0.2033E-02	0.1653E-03
40.00	493.68	0.2026E-02	0.1641E-03
20.00	484.94	0.2062E-02	0.8505E-04
20.00	481.96	0.2075E-02	0.8610E-04
20.00	488.21	0.2048E-02	0.8391E-04
10.00	479.90	0.2084E-02	0.4342E-04
10.00	478.43	0.2090E-02	0.4369E-04
10.00	482.63	0.2072E-02	0.4293E-04
5.00	474.53	0.2107E-02	0.2220E-04
5.00	471.58	0.2121E-02	0.2248E-04
5.00	474.62	0.2107E-02	0.2220E-04
2.50	465.88	0.2146E-02	0.1152E-04
2.50	465.39	0.2149E-02	0.1154E-04
2.50	468.07	0.2136E-02	0.1141E-04
1.25	459.32	0.2177E-02	0.5925E-05
1.25	459.80	0.2175E-02	0.5913E-05

E (KCAL/MOLE) 0.446297E 02
A (SEC-1) 0.361038E 19

DEGREES	K	PERCENT, UNREACTED, (TIME IN YEARS)				
KELVIN	(SEC -1)	1.0	2.0	5.0	10.0	20.0
298.0	0.67E-14	100.00	100.00	100.00	100.00	100.00
323.0	0.23E-11	99.99	99.99	99.96	99.93	99.86
348.0	0.34E-09	98.94	97.90	94.83	89.93	80.87
373.0	0.25E-07	44.81	20.08	1.81	0.03	0.00


CONTROL
ACTIVATION ENERGY = 44.6 KCAL per MOLE
FREQUENCY FACTOR = .36 X 10^19 per SECOND
STATISTICALLY COMPATIBLE
PHI/TSQUARE
.0019
.0020
.0021
.0022
1/T